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VOLUME 1 NUMBER 2

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ARCHIVES OF SURGERY

VOL. 1 SEPTEMBER, 1920 No. 2

THE DISTRIBUTION OF ADENOMYOMAS CONTAINING UTERINE MUCOSA *

THOMAS S. CULLEN, M.B.
BALTIMORE

At a meeting of the Johns Hopkins Hospital Medical Society in March, 1895, I reported my first case of adenomyoma of the uterus, and since then I have been on the lookout for tumors of this character. From time to time the results of my labors have been recorded either in book form or in the literature.

I have been amazed at the widespread distribution of these tumors consisting of nonstriped muscle with islands of uterine mucosa scattered throughout them. In May, 1919, I read a short paper on the subject before the New York State Medical Society at Syracuse. This fragmentary article was published [1] a few months later.

In the present paper I shall not attempt to cover the literature on the subject, but I shall confine my remarks to a description of the cases and of the pathologic material that I have personally observed since reporting my previous cases.

Thus far I have found uterine mucosa in ten places in the body as indicated in Figure 1, and I shall therefore discuss the subject under the following heads:

1. Adenomyoma of the body of the uterus.
2. Adenomyoma of the rectovaginal septum.
3. Adenomyoma of the uterine horn, or of the fallopian tube.
4. Adenomyoma of the round ligament.
5. Uterine mucosa in the ovary.
6. Adenomyoma of the utero-ovarian ligament.
7. Adenomyoma of the uterosacral ligament.
8. Adenomyoma of the sigmoid flexure.
9. Adenomyoma of the rectus muscle.
10. Adenomyoma of the umbilicus.

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* Address in surgery delivered before the Western Surgical Association in Kansas City, December, 1919.

* From the Gynecologic Department of the Johns Hopkins University and of the Johns Hopkins Hospital.

1. Cullen, T. S.: The Distribution of Adenomyomata Containing Uterine Mucosa, Am. J. Obst. **80**:130 (Aug.) 1919.

ADENOMYOMA OF THE BODY OF THE UTERUS

These tumors may be limited to the anterior or posterior walls of the uterus, or they may form a mantle or zone just outside the uterine mucosa. When the uterus is cut open, it is noted that the anterior or posterior wall, or both, are thickened. This increase is due to a coarsely striated condition of the muscle directly beneath the uterine mucosa. Where the uterine walls are especially thick, the diffuse myomatous growth may be several centimeters in thickness. Scattered throughout the diffuse growth, one often notes small cystlike spaces filled with chocolate-colored contents, and not infrequently with a loupe one can detect here and there uterine mucosa penetrating into the diffuse growth.

Occasionally a cystlike space, 1 cm. or more in diameter, may be found in the thickened uterine wall. Such a space will usually be lined with a velvety membrane about 1 mm. thick, and the cavity will be filled with the characteristic chocolate-colored contents — old menstrual blood.

The line of demarcation between the normal outer uterine muscular wall and the diffuse myomatous growth just beneath the mucosa is invariably sharply defined, but the two are nevertheless so closely blended that it would be absolutely impossible to separate them. Occasionally such a uterus will contain one or more small discrete myomas.

The histologic picture in a typical case is very characteristic: The uterine mucosa is often of normal thickness and looks perfectly natural, but as we approach the underlying diffuse myomatous tissue the mucosa is seen to penetrate it in all directions, sometimes as an individual gland; but often large areas of mucosa are seen extending into the depth. In favorable sections, one can follow a prolongation of the mucosa half way through the uterus. Where the diffuse myomatous growth ends, the outward extension of the glands also ends.

In the course of time, portions of the diffuse adenomyoma may project into the uterine cavity and be expelled through the cervix as submucous adenomyomas. In other instances a portion of the growth is forced to the outer or peritoneal surface forming a subperitoneal adenomyoma. Such a myoma is prone to become cystic, and the cyst cavity or cavities will be filled with chocolate-colored contents.

Symptomatology.—It is not difficult to figure out to what symptoms an adenomyoma of the uterus will usually give rise. In the first place, the mucosa lining the uterine cavity is perfectly normal, hence, as a rule, we shall have no intermenstrual discharge. With the advent of the menstrual period, however, the patient will not only lose her normal quota of blood, but this will be greatly increased by the flow coming from the large areas of mucosa which are scattered throughout the diffuse myomatous growth.

There will, as a rule, be a great deal of pain in the uterus at the period due primarily to the swelling of the mucosa which is scattered throughout the uterine walls. The small and medium-sized cystic spaces filled with chocolate-colored fluid are due to the accumulation of old menstrual blood in areas where the continuity of the mucosa with the uterine cavity has been interrupted. Such areas also undoubtedly add to the feeling of distention and discomfort at the period.

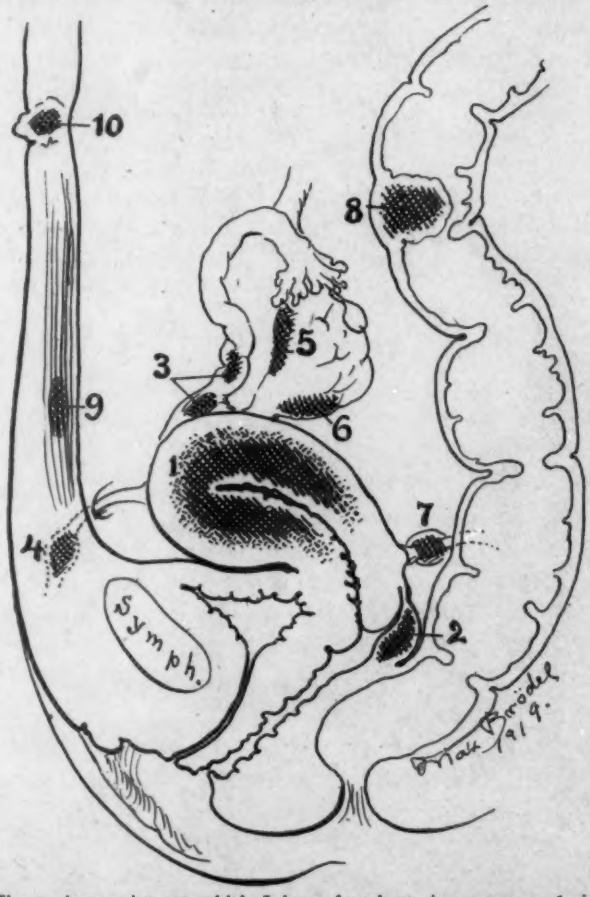

Fig. 1.—The various points at which I have found uterine mucosa: 1, in adenomyoma of the body of the uterus; 2, in adenomyoma of the rectovaginal septum; 3, in adenomyoma of the uterine horn or fallopian tube; 4, in adenomyoma of the round ligament; 5, in the hilum of the ovary usually unaccompanied by a myomatous growth; 6, in the utero-ovarian ligament; 7, in the uterosacral ligament; 8, in the sigmoid flexure; 9, in the rectus muscle; 10, in adenomyoma of the umbilicus.

On bimanual examination, the uterus is found to be normal in size and perfectly smooth, or, on the other hand, it may be two or three times its normal size and slightly nodular. The introduction of a uterine sound usually reveals a normal cavity, and on curettage normal mucosa is invariably found. From the clinical findings one can often make a fairly accurate diagnosis of adenomyoma.

Generally speaking, removal of such a uterus is clearly indicated. Frequently this proves rather difficult on account of the tendency for such an organ to become densely adherent to surrounding structures.

I have discussed adenomyomas of the body of the uterus in such detail elsewhere[2] that a further consideration of the subject here would be superfluous.

CASE 1.—*A bicornate uterus with diffuse adenomyoma of the right horn. Pregnancy in the right fallopian tube. Adenomyoma and hydrosalpinx of the left tube. Large cyst of the left ovary* (Figs. 2, 3, 4, 5 and 6).

History (Church Home and Infirmary, No. 19173).—Mrs. H. T., aged 36, admitted to the Church Home and Infirmary, May 21, 1918, and referred to me by Dr. Marshall G. Smith, complained of an abdominal tumor, increasing pain in the right lower abdomen and vaginal bleeding.

The menstrual periods as a rule had been regular, lasting two days, and she had had pain in the right lower abdomen. Latterly the periods had been irregular. The last normal period began probably Feb. 25, 1918. During March and April, she had had no menstrual period, but had suffered from the usual right-sided pain. She again had noted a flow on May 1, which had lasted one day. Two days had elapsed and then she had had a flow for seven days. The patient had been married twice, but had had no children and no miscarriages.

On examination under anesthesia, I made out what appeared to be a myomatous uterus which extended well up toward the umbilicus.

Operation and Result.—Operation was performed May 28. When the abdomen was opened we found the tube on the right side 4 cm. in diameter, and adherent in the pelvis. The uterus was bicornate, and the right side was three times the natural size. The surface of one of the nodules had a brownish appearance suggestive of an adenomyoma. On the left side was an ovarian cyst which filled the pelvis and was glued down by adhesions. We removed the structures from left to right and then took out the appendix which was tied down. The abdomen was closed without drainage. The patient made a good recovery and was discharged, June 18.

Examination of Specimen (Gyn. Path. No. 25515).—The specimen consists of the pelvic structures intact (Figs. 2 and 3). The uterus has been amputated through the cervix. This portion consists of a right and left uterine horn. The right horn is 9 cm. long and 5.5 cm. broad. This has two or three small bosses projecting from its surface, the largest being 1.5 cm. in diameter. The surface of the last and some of the others and also the adjoining peritoneum has a rusty appearance, instantly suggesting adenomyoma. On the anterior surface of the uterus are a few adhesions, on the posterior surface, many fanlike adhesions.

Intimately blended with the right enlarged uterine horn is a left uterine horn. The two horns are separated from each other by a cleft, about 1.5 cm. deep anteriorly, but very shallow posteriorly. The left horn to the point of amputation of the cervix is 7 cm. long and about 3 cm. broad.

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2. Cullen, T. S.: Adenomyoma uteri diffusum benignum, Johns Hopkins Hospital Reports **6**:133, 1896; Adenomyome des Uterus, Berlin, August Hirschwald, 1903; Adenomyoma of the Uterus, J. A. M. A. **50**:107 (Jan. 11) 1908; Adenomyoma of the Uterus, Philadelphia, W. B. Saunders Company, 1908.

On section, it is seen that both the right and the left horns have separate cavities. These apparently unite near the external os.

The right horn on section presents the typical picture of adenomyoma (Fig. 4). The anterior wall of the right horn reaches a thickness of more than 4.5 cm. There is no vestige of normal muscle persisting. The entire wall of the uterus both anteriorly and posteriorly shows the striated picture characteristic of adenomyoma, and scattered everywhere throughout both the anterior and posterior walls are chocolate-colored areas varying from 1 mm. to 5 mm. in diameter, while small chocolate-colored cysts are also found in the myomatous nodules on the surface of the uterus.

The walls of the left uterine horn present the normal appearance.

The right tube near the uterus is about 8 mm. in diameter. As it passes outward and downward, it reaches a diameter of 4 cm. On section, it is found to be filled with what looks like organized blood (Fig. 3).

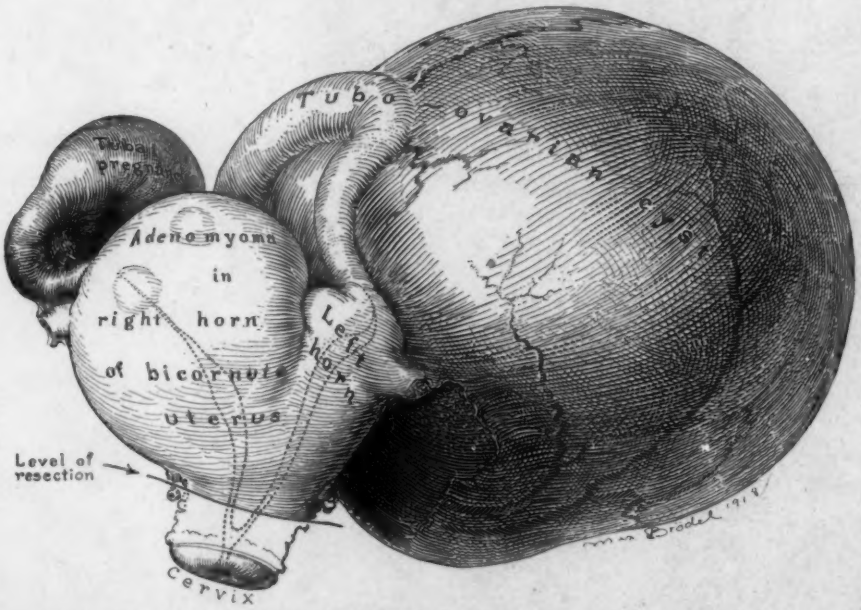


Fig. 2 (Case 1).—A bicornate uterus with adenomyoma of the right horn; right tubal pregnancy; enlarged left tube, the inner end showing adenomyoma (Fig. 6), the outer end hydrosalpinx; left ovarian cyst. For the finer details see Figure 3.

The left ovary has been transformed into a thin-walled multilocular cyst, 16 cm. in diameter. Its walls in places are as thin as parchment. The left tube at the uterine cornu is fully 1 cm. in diameter. As it passes outward it comes to measure about 2.5 cm. in diameter, and the walls are very thin.

Histologic Examination.—Right Uterine Horn: Sections have been made embracing the entire thickness of the uterus (Fig. 5). The musculature is divided up into diffuse whorls, varying from 5 mm. to 3 cm. in diameter. Some of these are oval or circular; others are long and run parallel to the cavity of the uterus. Scattered everywhere throughout the walls of the uterus are dark areas containing minute cavities in their centers. Some of these cavities have a definite lining fully 1 mm. in thickness. In various places are oval or irregular cystlike spaces varying from 1 to 4 mm. in diameter. The

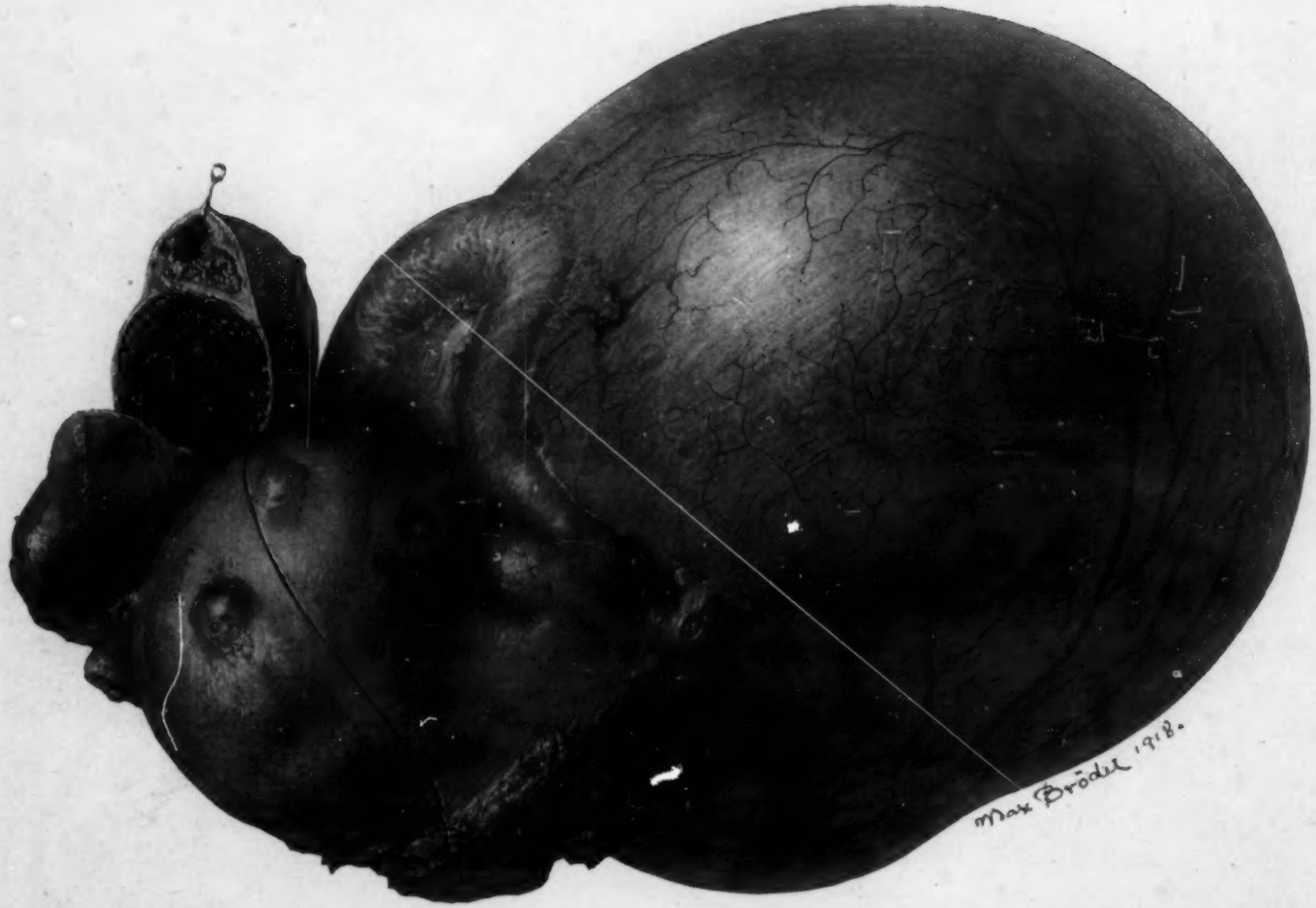


Fig. 3 (Case 1).—Bicornate uterus, right tubal pregnancy, enlarged left tube, left ovarian cyst. Viewed from the front. The uterus has been amputated through the cervix. The right cornu is much enlarged and projecting from its surface are two small fibroids. Beneath the anterior fibroid, the surface of the uterus is somewhat puckered . At this point the adenomyoma had extended to the peritoneal surface. A longitudinal section of the right horn is shown in Figures 4 and 5. The left uterine horn is relatively small. The left tube in its inner portion is almost solid and consists of typical adenomyomatous tissue (Fig. 6). The outer end of the tube has been converted into a hydrosalpinx. The ovarian cyst seemed to be of the retention cyst variety.

majority of these are partially filled with blood. Even with the naked eye the diagnosis of diffuse adenomyoma occupying both the anterior posterior uterine walls is perfectly evident.

With a higher power, islands of normal-appearing uterine mucosa are seen scattered everywhere throughout the diffusely thickened uterine walls, and the glands extend right up to the peritoneal surface. Even the isolated glands are accompanied by the characteristic stroma. In this case, the muscular tissue immediately around the islands of mucosa is unusually dense. Some of

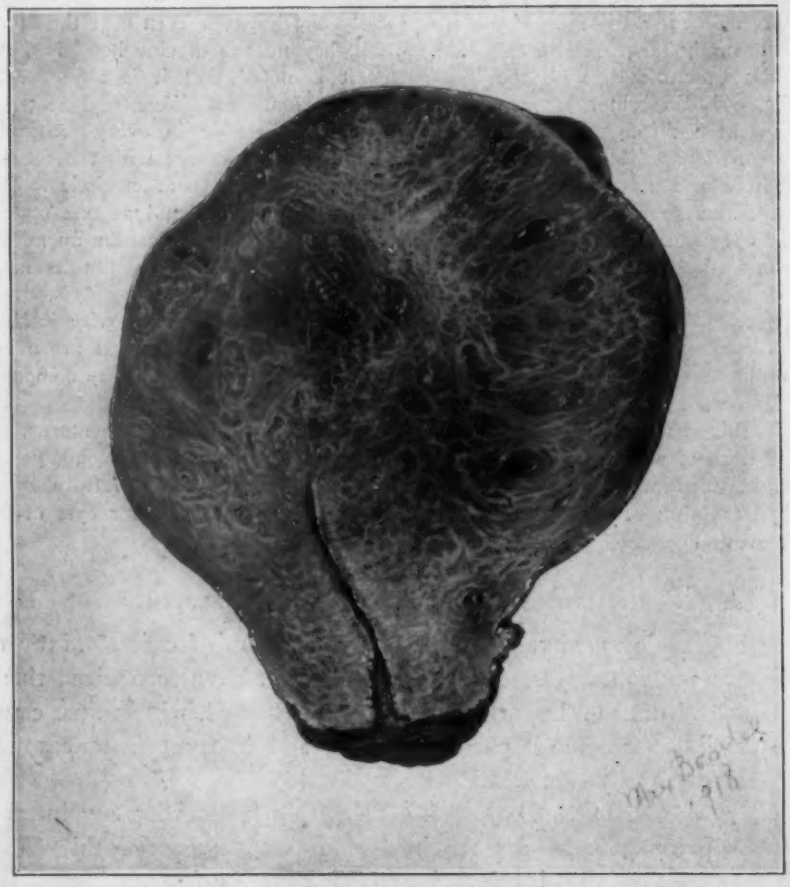


Fig. 4 (Case 1).—Adenomyoma of the right uterine horn. This is a longitudinal section through the right horn of the uterus shown in Figure 3. The entire body of the uterus shows a diffuse myomatous thickening, and scattered throughout the walls are small cystlike spaces. These were in the main filled with chocolate-colored contents. The diffuse adenomyoma extends right up to the peritoneal surface at most points. At the fundus a discrete myomatous nodule can be seen. For the low power picture of the adenomyoma see Figure 5.

the blood at the menstrual period has undoubtedly escaped to the peritoneal surface, thus accounting for the rusty appearance noted on the surface of the uterus at operation.

This is the most widespread adenomyoma of the uterus that I have ever seen. The mucosa lining the cavity of the uterus is perfectly normal. In a few places, however, it shows some tendency to extend into the underlying muscle.

Right Side: Sections from the blood clot in the right tube show quantities of placental villi. On some of these both Langerhans' layer and syncytium are still visible, and one is also able to make out syncytial buds. At other points, the villi have lost all trace of epithelium. No cellular structure is visible in the stroma, and the cells are recognized as mere shadows. Their contours are still perfectly preserved. We are dealing with a right-sided tubal pregnancy, and as we look back over the history we find that the menstrual cycle strongly indicated extra-uterine pregnancy, but that the relatively large size of the pelvic masses completely overshadowed the enlargement of the tube.

Left Side: As was noted macroscopically, the left tube even near the uterus is unusually large. A section taken 2 cm. beyond the uterine horn is 1 cm. in diameter. Even with the low power it is noted that it is almost solid (Fig. 6). Its center is occupied by diffuse myomatous tissue, and scattered everywhere throughout this are glands which resemble in every particular uterine glands. The majority of these lie in direct contact with the muscle, but here and there are several glands embedded in the characteristic stroma of the uterine mucosa. Some of the glands are dilated and at one or two points we can see miniature uterine cavities. We have in this tube an adenomyoma of the uterine type, and I am totally at a loss to explain its mode of origin.

Sections from the large ovarian cyst show that the largest cavity is lined with epithelium that is almost flat. In the walls of this large cyst are a few glandlike spaces lined with cuboidal epithelium. The cyst walls are composed of laminated fibrous tissue.

In this case, we have a most unusual combination: a bicornate uterus, the right horn of which presents a most beautiful example of diffuse adenomyoma; a right tubal pregnancy; adenomyoma of the inner end of the left tube and a hydrosalpinx of its outer end, and finally, a large multilocular cyst of the left ovary apparently of the retention cyst variety.

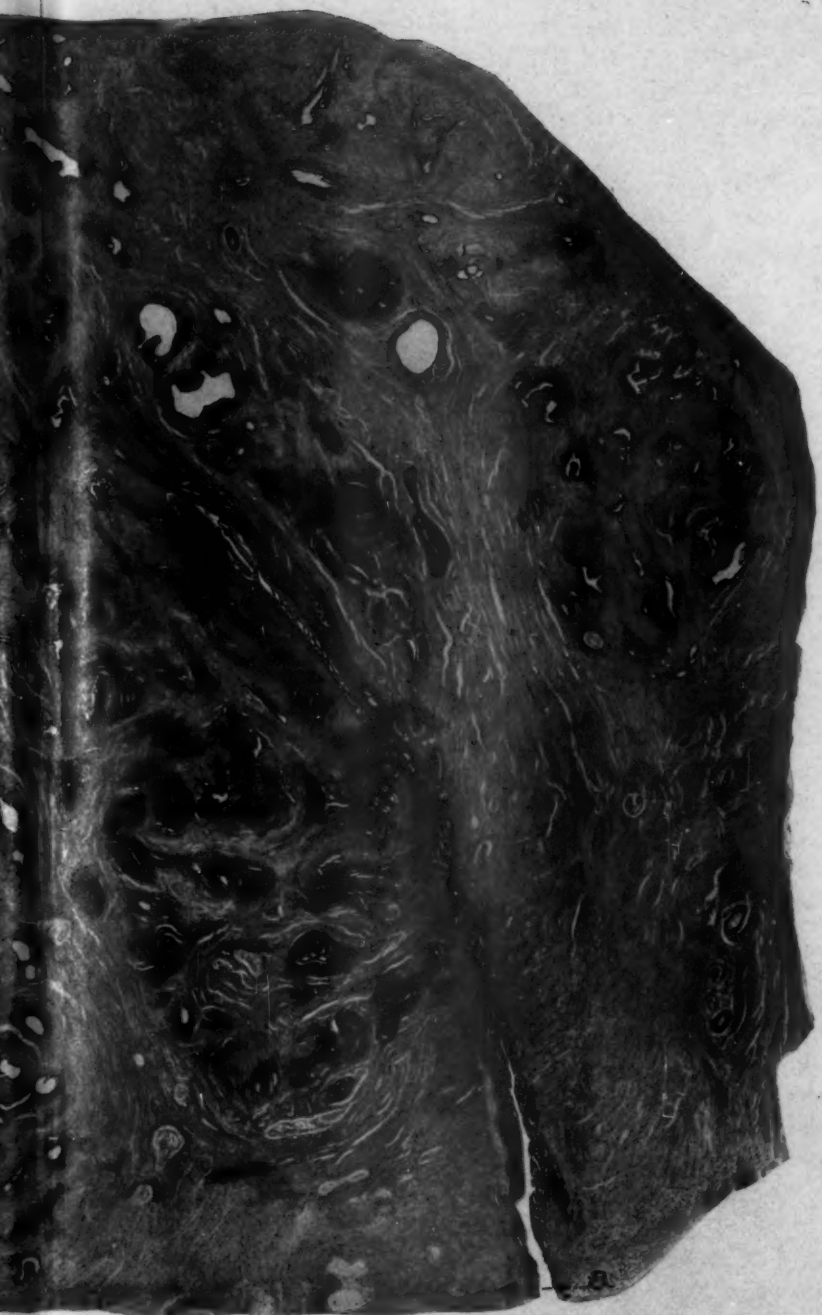
ADENOMYOMA OF THE RECTOVAGINAL SEPTUM [3]

I wish to lay unusual emphasis on this group of cases. Many of you have undoubtedly seen them, but may not have recognized them. They are of unusual importance, and, if overlooked, will in time cause the patient to become a chronic invalid, and in some instances will undoubtedly lead to her death.

In 1913, Dr. D. S. D. Jessup of New York, knowing my interest in adenomyomas, sent me specimens of two tumors of this class. The mail on the following morning brought me the *Proceedings of the Royal Medical and Chirurgical Society of London,* containing Cuthbert Lockyer's splendid article on "Adenomyoma of the Rectovaginal Septum." These two communications set me thinking, and I at once felt sure that two of my cases undoubtedly belonged in this category,

3. Cullen, T. S.: Adenomyoma of the Rectovaginal Septum, J. A. M. A. **62**:835 (March 14) 1914; Tr. South. Surg. & Gynec. A. **26**:106, 1913; A Further Case of Adenomyoma of the Rectovaginal Septum, Surg., Gynec. & Obst. **20**:260 (March) 1915; Adenomyoma of the Rectovaginal Septum, Bull. Johns Hopkins Hosp. **28**:343 (Nov.) 1917.

Fig. 5 (Case 1).—Diffuse adenomyoma of the uterus. This is a longitudinal secti
slit *a*, noted in the lower and right portion of the picture, represents the uterine cav
whole present the usual appearance. The posterior wall of the uterus is somewhat th
a diffuse myomatous thickening, and where the muscle is arranged in whorls there
are dilated, forming round, oval, or irregular cyst cavities. The glands extend right
adenomyoma of the uterus.



nal section through the right horn of the uterus shown in Figures 3 and 4. The longitudinal
rine cavity. It can be traced upward and toward the left. The glands of the mucosa on the
ewhat thickened and the anterior wall markedly so. The greater part of the uterus presents
there is nearly always a gland or a colony of glands in its center. Many of the glands
l right up to the peritoneal surface. The picture is that of a most pronounced diffuse

although the histologic examination had given no inkling of such a condition. I had many more sections made and was finally rewarded by finding in each case the typical picture in other portions of the specimen. Since then I have been on the lookout for this condition and have had nineteen cases.

Adenomyoma of the rectovaginal septum usually starts just behind the cervix, and on bimanual examination, one can feel in this region a small, somewhat movable nodule scarcely more than a centimeter in diameter. The rectal mucosa at this time can be made to slide perfectly over the tumor.

As the growth increases in size, it spreads out laterally and at the same time becomes blended with the adjacent anterior rectal wall. Later it may invade the broad ligaments, encircling the ureters, or may envelop pelvic nerves. With the extension of the growth, it may push down into the posterior vaginal vault forming definite and well-formed vaginal polypi, and finally, it may break into the vagina.

The histologic picture is typical of adenomyoma; even the vaginal polypi consist of nonstriped muscle and uterine mucosa covered over by vaginal mucosa. Where the growth has definitely broken through into the vagina, we have normal-appearing uterine mucosa lining portions of the vaginal vault.

The clinical picture in adenomyoma of the rectovaginal septum is typical. In the early stages, the patient comes complaining of much pain just before and at the beginning of the period especially at the time of defecation. On bimanual examination a small nodule is felt directly behind the cervix.

When the process is more advanced, the growth may measure 2 or 3 cm. across and may bulge slightly into the rectum, while in some cases there is already marked thickening of the anterior rectal wall for a distance of several centimeters, and at the period there may be some rectal bleeding.

The growth sometimes encircles one or both ureters. At the period, the tumor tissue naturally swells up, and it may so constrict one or both ureters that there is a damming back on one or both kidneys with consequent pain in the renal region. In other cases when the pelvic nerves are caught in the growth, excruciating pelvic pain may be experienced as soon as the tumor becomes congested at the time of menstruation.

Occasionally, as the growth progresses, the polypoid condition in the vaginal vault directly behind the cervix becomes very prominent, and in those cases in which the growth breaks through the vaginal mucosa, there may be a menstrual flow from the vaginal vault even when a supravaginal hysterectomy has been performed some years before for uterine myomas. Finally, if nothing is done, the pelvis

may become so choked with the growth that the patient dies from the extreme loss of blood coupled with partial intestinal obstruction.

In the early stages of the growth, this condition should be readily diagnosed. It cannot at this time be confused with any other pelvic lesion.

Treatment.—In the very early stages it may be possible to open up the vaginal vault just behind the cervix and remove the tumor. As

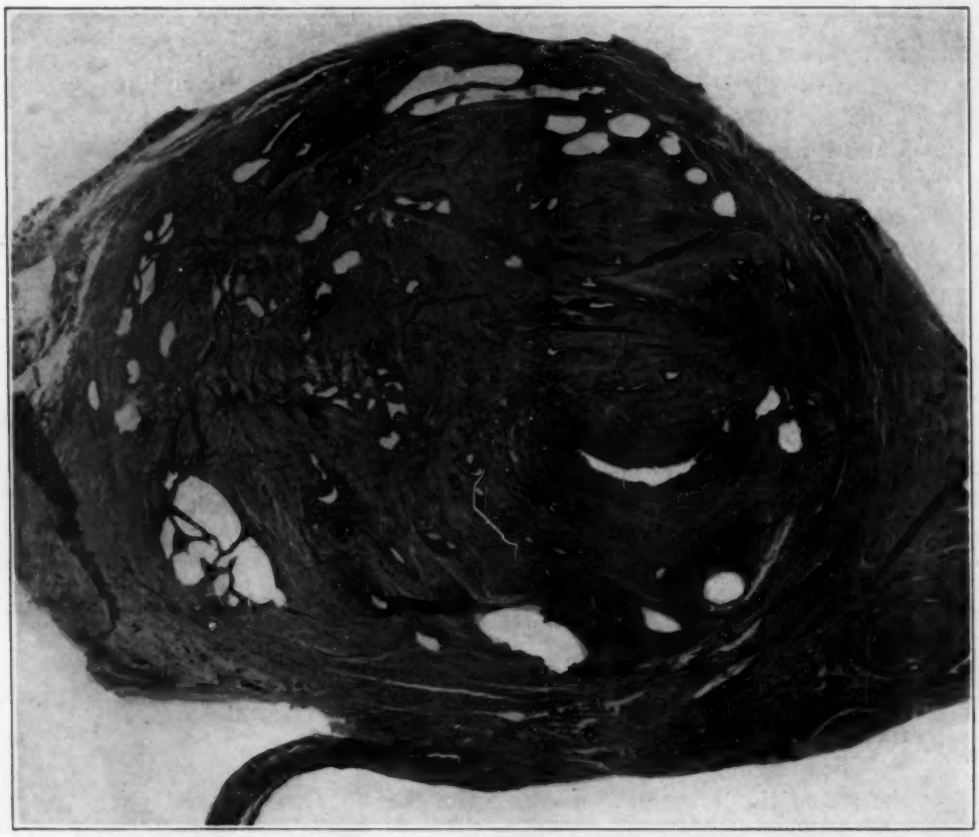


Fig. 6 (Case 1).—Adenomyoma of the left fallopian tube. This section was taken from the left tube seen in Figure 2, about 2 cm. distant from the uterine horn. Here the lumen of the tube is almost completely replaced by a diffuse myomatous growth with isolated glands or groups of glands scattered throughout it. The majority of the glands lie in direct contact with the muscle, a few are surrounded by the characteristic stroma of the uterine mucosa. Quite a number of the glands in the outlying portions have become dilated, forming small cysts. Hitherto I have never seen the lumen of the tube occupied by an adenomyoma. The distal end of the tube formed a hydrosalpinx.

a rule, however, it involves the posterior part of the cervix and cannot be shelled out.

When the nodule is 1 cm. or more in diameter and is still freely movable, the abdomen should be opened, the ureters isolated and the uterus with a cuff of vaginal mucosa removed. If the vagina is cut

Fig. 7 (Case 2).—Adenomyoma of the rectovaginal wall as seen on vaginal inspection. This water color of the uterus and accompanying vaginal cuff was made by Mr. Brödel shortly after operation. The cervix itself is practically normal. Projecting from its surface are a few small Nabothian follicles. Just posterior to the cervix is a slightly bluish black cystic area about 6 mm. in diameter. This bluish black appearance is, of course, due to the accumulation of old menstrual blood in a small cystic area in the adenomyoma. The uterus itself is little if any enlarged. For the appearance of the adenomyoma on section, see Figure 8, and for the microscopic picture, see Figure 9.

completely across, one can then lift the uterus and vaginal cuff up and with more ease separate the adherent vaginal cuff from the rectum. Sometimes it will be necessary to remove a wedge of the adherent anterior rectal wall with the uterus.

In cases in which the growth is widespread, a preliminary permanent colostomy is imperative. Later the pelvic structures can be removed *en bloc*. The removal of an extensive adenomyoma of the rectovaginal septum is infinitely more difficult than a hysterectomy for carcinoma of the cervix.

When a hysterectomy has been performed, and a small portion of the growth has been left on the rectum, radium seems to have held the rectal growth in check.

Since my last paper on adenomyoma of the rectovaginal septum appeared I have had ten more cases. The majority of these were early cases, and it is in the early cases that we naturally get the best results. History will undoubtedly repeat itself. Twenty-five years ago, a subacute or chronic appendix was rarely removed; but appendix abscesses were drained. Now the appendix is, in the vast majority of cases, removed in time. In less than ten years, I feel sure that the surgeon will recognize and operate on these adenomyomas of the rectovaginal septum long before the wall of the rectum or the broad ligaments have been involved. Given a small nodule directly behind the cervix with little evidence of pelvic infection, the diagnosis is relatively certain. If the abdomen is then opened and the rectum is found lifted up and adherent to the posterior part of the cervix, the chances are nine out of ten that an adenomyoma of the rectovaginal septum exists. When early operation is performed in these cases, a certain number of our "mild pelvic inflammatory cases" that heretofore have gone from bad to worse will be cured. In the first week of November of this year, I saw three early cases of adenomyoma of the rectovaginal septum — all of the patients being residents of Baltimore.

Recently I received a letter from a surgeon in South America in which he sketched his case from the early to the inoperable stages. The history is so graphically given that I believe we shall all profit by hearing it.

Valparaiso, Oct. 18, 1918.

Dear Sir:

Having found your articles on "Adenomyoma of the Recto-Vaginal Septum" of special interest, I take the liberty of sending you details of a case which was a puzzle to two other surgeons and myself until I luckily saw a synopsis of your article on this disease in *Surgery, Gynecology and Obstetrics*. The said article cleared up a mystery which I had been trying to solve for months, as it is impossible to find details of such cases in well-known text-

books in English, German or French. I think it will be of interest for you to know of such a case and hope you will have patience to read this letter which I make as short as possible.

Mrs. H., aged 30, nullipara, of good health, married two years ago, consulted us (in British and American Hospital) at the beginning of December, 1917, complaining of lumbago. On making a vaginal examination, we asked her about the menses which she said had been of late painful on the right side; the uterus was normal in position, size, consistency, etc. On the right side, the ovary was painful, but the puzzle was that she had a nodule especially hard and painful near the uterus which we took to be localized parametritis. We advised her to take douches, baths, ichthyol suppositories, etc., but seeing we got no result and that the pain was excruciating during the next period we decided to make a laparotomy.

On January 3, we performed a median laparotomy finding a right ovary large and of a very dark, unhealthy color. The nodule mentioned before was in the broad ligament right over the vagina, and it being impossible to remove it by abdomen, we resolved to leave it. The uterus was normal so we left it as it was, removing the ovary.

For three months, the patient experienced relief in symptoms, but on the fourth month menstruation was very painful and the pain radiated down to the thigh. We made again a vaginal examination and greatly to our disappointment found now two hard nodules, the same one as before much increased in size and a second one in the recto-vaginal septum which was easier to touch by rectal examination. The pain on palpation was terrible, so we had to give the patient a few drops of ether to examine carefully.

Seeing the condition of affairs, we had a consultation with a third surgeon and he was as much puzzled as we were. We decided to remove these little tumors by the vaginal route.

On May 28, we removed the two tumors by the vaginal route and our pathologist reported adenocarcinoma of an unusual type.

Looking for some information on this subject, I came across the article already mentioned and immediately sent for the more lengthy article in the *Johns Hopkins Bulletin* which I received the day before yesterday and which has cleared up the condition of affairs to us and corrected the pathologist's diagnosis.

Unluckily our patient's condition is now too bad for us to think of doing a complete hysterectomy and we think she will not live very long. She has not had as yet any rectal hemorrhage, but she has had ovarian insufficiency, very irregular menstruation and her general state is very poor. Locally the condition of the pelvis is one firm mass as you say, like glue.

As I have not been able to procure your former articles, I beg your patience to answer one or two questions by post.

Where does this abnormal muscular and glandular tissue come from? From the uterus, or are these sometimes remains of fetal tissue or rather embryonic tissue which suddenly give rise to the growth?

Thanking you for the special service rendered to us through your articles and hoping you will let me know of any further researches in this line, believe me,

Yours truly,

JOHN WILSON, M.D.

REPORT OF CASES OF ADENOMYOMA OF THE RECTOVAGINAL SEPTUM HITHERTO UNPUBLISHED

CASE 2 (Septum Case 10).—*Adenomyoma of the rectovaginal septum recognized as an indurated area just posterior to the cervix, and by a small bluish black cyst shining through the vaginal mucosa* (Figs. 7, 8 and 9).

History (C. H. I. No. 18650).—Mrs. M. L., aged 41, was admitted to the Church Home and Infirmary, March 6, 1918, complaining of pain in the right

Fig. 8 (Case 2).—Adenomyoma of the rectovaginal septum. This is a longitudinal section of the uterus and vaginal cuff seen in Figure 7. Near the internal os are a few small cysts, otherwise the uterus presents the normal appearance. The anterior vaginal wall is normal. In the posterior vaginal wall near the cervix is an area of thickening with small dark areas scattered throughout it. On histologic examination (Fig. 9), it presents the typical picture of an adenomyoma.

lower abdomen associated with menstruation. Her general health had not been good. She had had pleurisy in 1916.

Her menses began at 13, were regular, painful and lasted seven days. Since November, 1917, the periods had been about three weeks apart and exceedingly painful. The last period was shortly before her admission.

Her present illness dated back one and a half years when she had an acute attack of pain in the right lower abdomen reaching to the back. This was definitely associated with menstruation. She had always gone to bed on the first day of the period and at times would become giddy and faint. For a year and a half, there had been a great deal of pain in the right lower abdomen at the time of the period. This pain would be sharp and radiating.

Examination.—When the patient was admitted to the hospital, she was in a very nervous and run down condition and her period was just over. Dr. Edmond H. Teeter, the resident who made a pelvic examination, told me

Fig. 9 (Case 2).—Adenomyoma of the rectovaginal septum. The majority of the glands are accompanied by the characteristic stroma of the mucosa. A few lie in direct contact with the muscle. For the appearance before operation, see Figure 7. A longitudinal section of the uterus and rectovaginal septum is shown in Figure 8.

before I had seen the patient that she had an adenomyoma of the rectovaginal septum. This was perfectly definite, as just posterior to the cervix was an area of induration about 2 or 3 cm. across and probably 1.5 to 2 cm. thick. On rectal examination, the anterior rectal wall seemed splinted.

Operation and Result.—March 26, 1918, we made a median incision and found a corpus luteum cyst, 5 cm. in diameter, on the left side. The left tube and ovary were at once removed. The uterus was gradually dissected free as far as its vaginal attachment, and both ureters were carefully dissected out.

The vagina was cut across all the way around, after which adhesions to the rectum were got at from the under side. It was possible to remove the growth without going into the lumen of the bowel at all. There was considerable oozing which was readily checked. Two drains were left in the pelvis and brought out through the vagina, one in the lower angle of the incision. The patient made a perfectly satisfactory recovery and was discharged April 21, 1918.

At the time of operation a small bluish black cyst was noted in the vagina directly behind the cervix (Fig. 7). This bluish black appearance clearly indicated that we were dealing with an adenomyoma.

A longitudinal section of the uterus (Fig. 8) shows that the organ is only slightly altered. In the vaginal wall just behind the cervix, however, is an area of thickening and this shows the characteristic areas of hemorrhage invariably associated with an adenomyoma.

Histologic Examination (Gyn. Path. No. 25514).—A section through the posterior vaginal wall at the point where the bluish black cyst was noted shows that the vaginal mucosa is normal. The underlying tissue consists of nonstriped muscle running in all directions. The cyst noted clinically is lined with low cuboidal epithelium. It is partially filled with old blood which presents a granular appearance, and in the blood are exfoliated epithelial cells which are swollen, have become spherical and are filled with yellowish brown pigment. Some of the epithelial cells lining the cyst present precisely the same picture. Projecting into the cyst cavity at one point is a tongue-like mass of normal uterine mucosa. The surface of this is covered with high cylindric epithelium. Beneath it is the characteristic stroma of the mucosa, and embedded in this stroma is a uterine gland which is continuous far into the depth of the myomatous tissue. Scattered at various points throughout the diffuse myoma are islands of typical uterine mucosa (Fig. 9), some presenting the usual appearance, others showing old hemorrhage. The stroma cells of the mucosa in such areas are swollen and have taken up yellowish brown pigment.

The mucosa lining the cervix and cavity of the uterus is normal.

In this case, the adenomyoma is lower down than usual and appears to have begun in the posterior vaginal wall rather than in the posterior part of the cervix.

CASE 3 (Septum Case 11).—*Adenomyoma of the rectovaginal septum* (Figs. 10 and 11).

History (Gyn. No. 24601).—Mrs. C. S. F. L., aged 41, came to see me on Jan. 6, 1919. She looked perfectly well but complained of pain in the lower part of the abdomen when she walked, and of excruciating pain in the midline above the symphysis at the time of the periods. She was also suffering a great deal of discomfort when the bowels moved.

The patient began to menstruate at 12, and was perfectly regular. The flow for the last three years had been very free, the periods persisting for six days. There was a great deal of abdominal pain on the third day. The last period was three weeks before her admission. She said she had a yellowish discharge between periods which at times was most irritating. The patient had had four children; no instruments were used in the deliveries.

Examination.—I found the abdomen to be perfectly uniform. There was a small hernia at the umbilicus 3 mm. in diameter. The outlet was moderately relaxed, the cervix was forward and slightly lacerated, and a little nodular thickening about 1.5 cm. in diameter could be felt distinctly, directly behind

the cervix. The body of the uterus was not enlarged, but was sagging backward. Rectal examination revealed the thickening posterior to the cervix very clearly.

Operation and Result.—The patient was admitted to the Johns Hopkins Hospital, Jan. 19, 1919, and operated on the following day. After tying off the round ligaments and opening up the broad ligaments, we tied the uterine vessels and isolated both ureters. We found a little puckering and thickening just posterior and a little to the right of the cervix near the right uterosacral ligament. We cut both uterosacral ligaments, turned down the bladder peritoneum, controlled the vaginal veins and then cut the vagina across all the way around. This enabled us to lift the uterus and rectum well up so that the nodule posterior to the cervix could be attacked from the under side. The growth was gradually loosened and separated from the rectum completely. We were able to accomplish this with the minimal amount of bleeding. The growth in the rectovaginal septum was about 1.5 cm. in diameter, and where the cervix had become adherent to the rectum, the puckered area had developed. As we lifted the cervix away from the rectum, there was an escape of a little old blood. The patient stood the operation perfectly. We removed the appendix and put two drains into the pelvis, bringing them out through the vagina. The patient made an excellent recovery and was discharged, Feb. 13, 1919.

On Saturday morning, June 29, 1919, five months after operation, the patient was taken with intense discomfort, not exactly pain, in the epigastrium. This was not very severe and in spite of it she went to Annapolis. On her return, there was no improvement, but she had a fair night with the aid of an opiate. On Sunday morning, Dr. Frank R. Smith was called but could discover no alarming symptoms. There was no abdominal pain, and no pain on palpation of the abdomen. Magnesium citrate and bismuth were prescribed and the bowels moved well. There was no blood passed in the stools. The patient vomited, but there was no unusual odor to the vomitus. Sunday evening, a hypodermic was given, and the patient rested until 2 o'clock Monday morning. On awakening, she complained of a more generalized pain and of a distress that was rhythmic in character. A little liquid nourishment was given, but this was immediately vomited. About half past six, an enema was given, and the water returned clear and free from blood. Suddenly the patient fell over, gasped a few times and died. The husband, who was a physician, noted the rapid heart beat and abnormal coldness of the arms some time before death. There was no clamminess or dyspnea noted at this time.

Necropsy Findings (J. H. H. Necropsy No. 5933).—This was performed by Dr. R. G. Mills. When the abdomen was opened the omentum was found firmly adherent to the under surface of the scar. At no point were there adhesions between the omentum and loops of intestine. As the intestines came into view, they appeared somewhat distended, a little dark in color. The lowermost loop was very dark and purplish, and the serosa of this dark colored loop had to some extent lost its luster, and the subcutaneous tissue appeared infiltrated with blood. There was a small amount of free, clear straw-colored fluid in the peritoneal cavity, and there were a number of small adhesions that connected the various loops of intestine. It was rather difficult to unravel the abdominal picture.

Dr. Mills' summing up is as follows: "Beginning at the point where the jejunum joins the ileum the bowel passes beneath the mass of adherent intestine, it passes under a fold of mesentery, it emerges below in the region of the cecum and is there united with another loop of bowel by a long, slender

strong band of adhesions. The ileum now passes into a long loop that circles around and is adherent once more to the long adhesion just mentioned. Just above this attachment the ileum is kinked into an S-shaped mass as the result of adhesions which attach contiguous mesenteric surfaces. The bowel then passes on in another loop returning beneath this long slender adhesion. At this point the lumen of the ileum is abruptly decreased in caliber and beyond this point is much smaller. At the point of constriction, the serosa is very deeply injected and somewhat consolidated. The bowel is much firmer by reason of a hemorrhage at the point where obstruction occurs.

"Subsequent to operation, it is probable that adhesions formed between contiguous loops of bowel. These have organized, producing distortion of the lumen of the bowel. The adhesions are probably responsible for the long slender adhesion above mentioned. Probably at the onset of the present acute attack a twist of the whole mass has occurred producing in effect a volvulus. This has thrown unusual tension on the narrow band which, producing a bridge-like form, has allowed a loop of ileum to pass beneath it."

Fig. 10 (Case 3).—Adenomyoma of the rectovaginal septum. Springing from the posterior surface of the uterus are a few small myomas. Growing from the posterior surface of the cervix just below the peritoneal attachment is a rough nodular growth. This on histologic examination showed typical adenomyoma (Fig. 11). As a rule, I never remove normal ovaries, but in some cases of adenomyoma of the rectovaginal septum it is necessary to leave a small portion of the growth attached to the rectum, and if the ovaries are saved there appears to be a tendency for the remaining portion of the adenomyoma to continue to grow.

Dr. Mills' findings disclose clearly the fact that intestinal adhesions had followed the abdominal operation and that several months later there was a sudden volvulus of the adherent intestinal mass producing acute obstruction. It is remarkable to find a patient succumbing so quickly after the symptoms of partial obstruction developed. It will be noted, however, that the upper part of the small bowel was much involved. In such cases alarming symptoms usually develop relatively early.

Examination of Specimen (Gyn. Path. No. 24657).—The specimen consists of the uterus with the appendages intact (Fig. 10). The uterus is 9 cm. long, 5 cm. broad and 5 cm. in its anteroposterior diameters. Both the anterior and posterior surfaces are smooth. In the posterior wall of the uterus are two small fibroids. These project a little from the surface. Springing from the

posterior wall of the cervix is a small, irregular growth about 1.5 by 1 cm. This is intimately blended with the cervical wall. In the depth, it contains several small bluish black areas.

There is a slight rolling out of the cervical mucosa. Situated in the anterior wall of the uterus is a myoma, 1.5 cm. in diameter. The uterine mucosa is normal.

The appendages on both sides are perfectly normal.

Histologic Examination.—The mucosa of the vaginal and cervical portions of the cervix is normal. The growth on the posterior surface of the cervix consists in large measure of fibrous tissue. It also contains a moderate amount of nonstriped muscle. Here and there in this diffuse growth are irregular deposits of uterine mucosa (Fig. 11). This in some places presents the normal picture, at other points it shows a mild grade of hypertrophy. Here and there the stroma of the mucosa shows hemorrhage.

We are dealing with a typical adenomyoma of the rectovaginal septum.

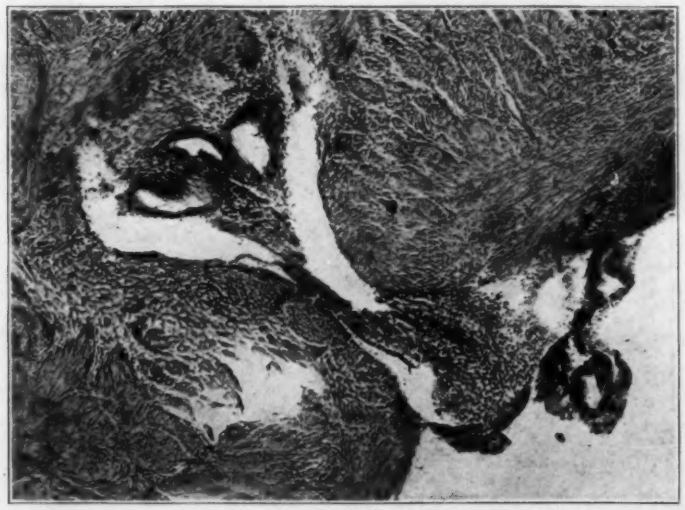


Fig. 11 (Case 3).—Adenomyoma of the rectovaginal septum. For the gross specimen see Figure 10. The tissue was very difficult to cut, hence the imperfect section. The glands of the growth are surrounded by the characteristic stroma.

Case 4 (Septum Case 12).—*Adenomyoma of the rectovaginal septum* (Figs. 12 and 13).

History (Gyn. No. 24585).—B. L., aged 25, admitted to the Johns Hopkins Hospital, Jan. 21, 1919, had had a dilatation and curettement at the Church Home and Infirmary following a miscarriage in June, 1910. On Oct. 28, 1911, she was admitted to the Johns Hopkins Hospital, and a diagnosis of chronic pelvic inflammation was made. I performed a dilatation and curettement, removed the right tube, the left tube and ovary and appendix. Laboratory examination (Gyn. Path. No. 16635) revealed acute endometritis, and (Gyn. Path. No. 16625) a double pyosalpinx, a relatively normal appendix, a cystic left ovary. There was nothing in the clinical history at that time to indicate adenomyoma.

The patient began to menstruate at 13, and was regular. Since the operation in 1911, the periods had occurred at intervals of from fifteen to twenty-one days and had lasted from six to seven days. She formerly had little menstrual pain, but for the last year the discomfort had been growing worse. The pain usually started when the period commenced, it might last for a couple of days. It was dragging, dull-aching in character, and she also had pain in the back. Her last menstrual period occurred after her admission to the hospital. There had been no interménstrual bleeding except on one occasion, a year before, after severe exertion. There was a slight leukorrhea just before and after the period. The patient had been married two years and

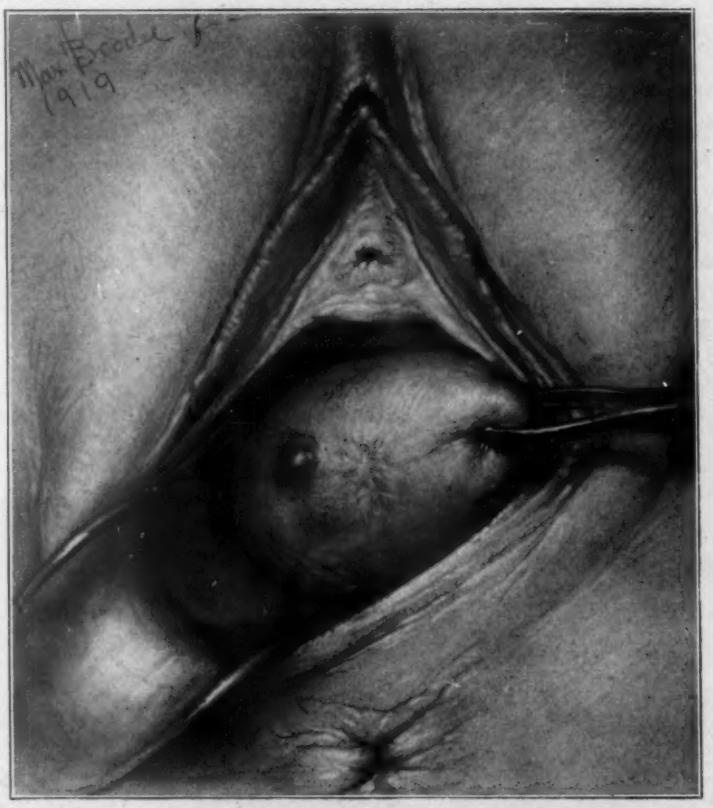


Fig. 12 (Case 4).—Adenomyoma low down in the rectovaginal septum. The cervix has been drawn strongly to the left. On the posterior surface high up are two small cysts. One stands out prominently, the other is rather hazy. Just below them, that is, toward the external os, the mucosa is definitely puckered. The low position of the growth enabled us to remove it with ease through the vagina. For the histologic picture see Figure 13.

a half. She had had no children, but she had had a miscarriage at six weeks in 1910. In 1913, a small lump was felt in the vaginal wall behind the cervix. At that time it was no larger than a pinhead. It had gradually increased in size and she now had two small nodules. These were not tender.

Examination.—On vaginal examination, the cervix was found to be normal in size. The body of the uterus was anteposed, and in good position. There was no thickening on either side. In the vaginal vault, slightly to the right

of the cervix, were two elastic spherical bodies each about 5 mm. in diameter. They lay close together and seemed really to form part of the same nodule. They were not fixed and occasioned no discomfort. When a speculum was introduced to the side of the cervix, one saw two small bluish cysts with slight puckering of the vaginal mucosa about the center of each of these small thickenings (Fig. 12).

Operation.—Jan. 25, 1919, I drew the cervix well over to the left, and on the right side of the vaginal vault lateral to the cervix there appeared two small areas darkish blue in color. These were incorporated in two small tumors

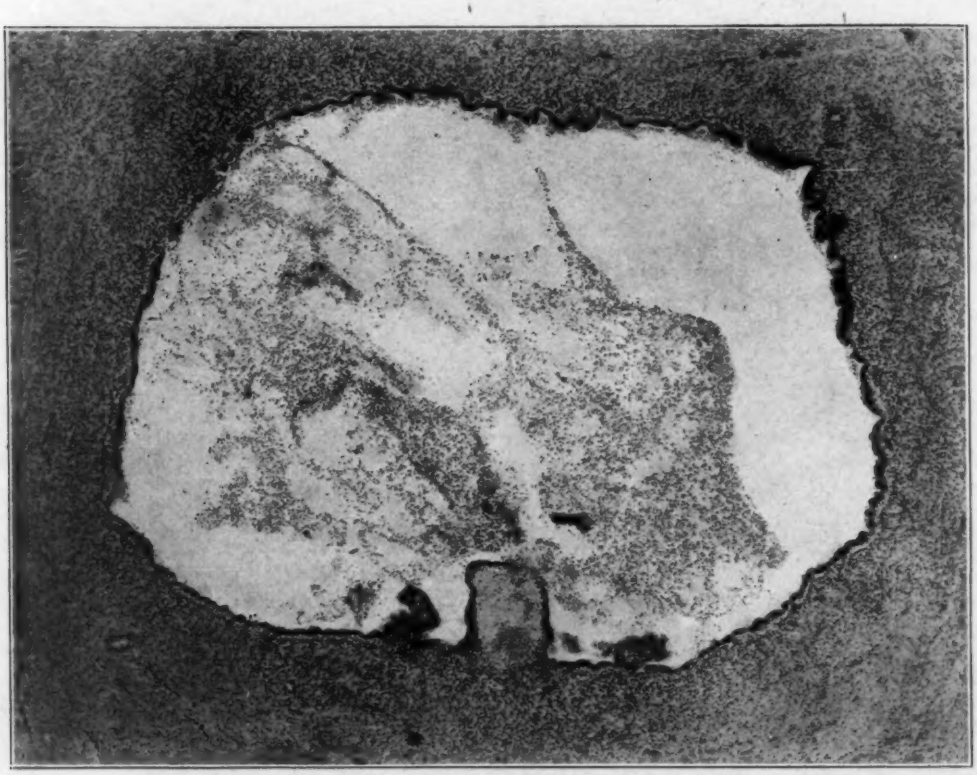


Fig. 13 (Case 4).—A small cyst in an adenomyoma of the rectovaginal septum. This is one of the small cysts noted in Figure 12. It is lined with one layer of cylindric epithelium of the body type, and extending into the cavity are several small projections. The cyst contained blood and some exfoliated epithelium. At some points, the cyst epithelium lay directly on the underlying muscle, in other places it was separated from the muscle by a definite stroma.

lying deep beneath the vaginal mucous membrane. I made an elliptical incision including these two small tumors. They were removed without any difficulty and the vaginal incision closed. The patient was discharged, February 5, in good condition.

Examination of Specimen (Gyn. Path. No. 24652).—The larger cyst reaches a diameter of 6 by 4 mm. Both cysts are surrounded by a definite layer of muscle arranged circularly. The cysts are lined by one layer of cylindric epithelium which is somewhat folded. In one of the cysts are definite projections (Fig. 13). Both cysts contained blood and in the underlying stroma and muscle are quantities of yellowish brown pigment.

This was undoubtedly another adenomyoma. It was situated much lower down than usual and we were accordingly able to remove it with the minimal amount of difficulty.

CASE 5 (Septum Case 13).—*Adenomyoma of the rectovaginal septum* (Figs. 14 and 15).

History (Gyn. No. 24864).—A. A., aged 26, was admitted to the Johns Hopkins Hospital, May 2, 1919, complaining of bearing down pains in the pelvis and of backache. The patient's mother died of some form of cancer. Menstruation began at 13, was regular and lasted from three to four days. She had pain for the first day, cramplike in character. There was no intermenstrual bleeding. The patient has been married seven years. She has had

Fig. 14 (Case 5).—Adenomyoma of the rectovaginal septum. Attached to the posterior surface of the uterus are a few adhesions. Springing from the posterior surface of the cervix below the peritoneal attachment is a well defined nodule, 2 by 1 cm. For the histologic picture of this nodule see Figure 15.

one child. About a year ago she began to have a dragging sensation in the lower abdomen; this was no worse at the periods. The symptoms had increased in severity.

Examination.—The patient was a well developed woman. The outlet was relaxed, the cervix was lacerated. Behind the cervix was a nodule about 1.5 cm. in diameter. This was not very tender. The uterus itself was normal in size and in good position. On the left side there was some thickening probably due to a prolapsed ovary. The patient had no hemorrhoids.

Dr. H. N. Shaw, the resident gynecologist, immediately thought of adenomyoma of the rectovaginal septum.

Operation.—May 3, under anesthesia, I confirmed Dr. Shaw's impressions. On examination, I found that the rectum was attached to the nodule posterior

to the cervix. The rectal wall did not seem to be invaded but was somewhat puckered at this point.

When the abdomen was opened, a little puckered area could be seen just posterior to the cervix. The rectum here was lifted up and had become adherent to the puckered area. The picture was that of a typical early adenomyoma of the rectovaginal septum. The operation was begun by tying and cutting the round ligaments on each side. The right ovarian vessels were clamped and cut. We decided to leave the left ovary. After freeing the broad ligaments on each side, they were spread widely apart and the inner flap was split down to the region of the ureter. Both ureters were now dissected out and the

Fig. 15 (Case 5).—Adenomyoma of the rectovaginal septum. This section is from the adenomyoma springing from the posterior part of the cervix in Figure 14. The muscular tissue is very dense. Scattered throughout it are isolated glands surrounded by the characteristic stroma.

uterine vessels ligated. The dissection was now carried down far in the vaginal vault, and the vaginal veins were clamped and tied. After sufficient exposure had been obtained in this manner, the uterosacral ligaments were cut and the uterus drawn well out. The vagina was then cut across well below the nodule in the rectovaginal septum and the thickened vaginal wall was gradually dissected free from the rectum. The bowel was in no way damaged. The appendix was removed, a small drain was left in the pelvis and brought out through the vagina, and the abdominal incision closed. The patient left the table in excellent condition. She was discharged, May 25, 1919.

Examination of Specimen (Gyn. Path. No. 24989).—The specimen consists of the uterus, right tube and ovary and appendix. The uterus is 8 cm. long, 6 cm. broad and 4.5 cm. in its anteroposterior diameters. The anterior surface of the uterus is smooth, the posterior surface is covered by a few shaggy adhesions, but is for the most part smooth. Projecting from the posterior surface of the cervix near the internal os is a nodule 2 by 1 cm. (Fig. 14). This is irregular. It blends into the cervical tissue, but the line of demarcation is sharply defined. Its superficial portion invades the surrounding adipose tissue. It contains a few minute brownish areas. The vaginal portion of the cervix shows some laceration. The uterine mucosa reaches 6 mm. in thickness.

The right tube is normal. The right ovary contains an unruptured corpus luteum, and the peritoneum over this area has been adherent.

Histologic Examination.—The mucosa of the vaginal portion of the cervix is normal. The cervical glands present the usual appearance. The nodule projecting from the posterior surface of the cervix consists of nonstriped muscle and fibrous tissue. Scattered throughout it are small irregular islands of uterine mucosa (Fig. 15). Near the point where the growth was attached to the rectum is a rather large area of mucous membrane showing the characteristic gland hypertrophy now and then noted in the mucosa of the body of the uterus.

This is a typical case of adenomyoma of the rectovaginal septum.

CASE 6 (Septum Case 14).—*Extensive adenomyoma of the rectovaginal septum; extension to the surface of the right fallopian tube; uterine mucosa on the surface of the right ovary* (Figs. 16, 17, 18, 19, 20 and 21).

History (Gyn. No. 24887).—L. G., aged 40, white, was admitted to the Johns Hopkins Hospital, May 9, 1919, complaining of dysmenorrhea and menorrhagia.

The patient had been in the hospital in 1912 (Gyn. No. 18377). At that time I performed a partial resection of both ovaries, released pelvic adhesions and removed the appendix.

She was again admitted to the hospital in 1915 (Gyn. No. 20850). At that time Dr. Neill, the resident, incised and cauterized a Bartholin's gland abscess.

The patient's menses were fairly regular and lasted seven days. There was a very profuse flow. The last period was April 20. There was no intermenstrual bleeding. The patient had always had very severe dysmenorrhea. This had become more distressing during the last year. The most acute pain was experienced a day before the period started. During the twenty-four hours before the onset of the flow the patient was nauseated, vomited, had extreme abdominal pain and pain in the back. These symptoms were getting worse.

The patient had been married fifteen years. She had one child, fourteen years ago, and no miscarriages.

Examination.—The patient was a rather delicate, undernourished, middle-aged woman. Her hemoglobin was 75 per cent., white blood cells, 11,000. The lower abdomen was prominent, due to a hard mass extending up from the pelvis and reaching to within about 4 cm. of the umbilicus. The outlet was moderately relaxed and the cervix was high up in the vaginal vault. It was continuous with the abdominal tumor.

Operation.—May 12, 1919, on examination under ether, the pelvis was found to contain a large mass about the size of a five-months' pregnancy. On the surface of this and also posteriorly, a hard nodule could be felt. In the rectovaginal septum on the left side was a dense indurated mass.

When the abdomen was opened, the uterus was found to be quite symmetrical and enlarged from the fundus to the cervix. The right tube was filled with fluid and was adherent to the uterus. The intestines were adherent to the posterior surface of the uterus. The culdesac was indurated, and the rectum was adherent well up on the posterior surface of the uterus. It was also firmly attached to the left broad ligament. The left tube was partly obscured by adhesions, and the left ovary was buried in adhesions. As a

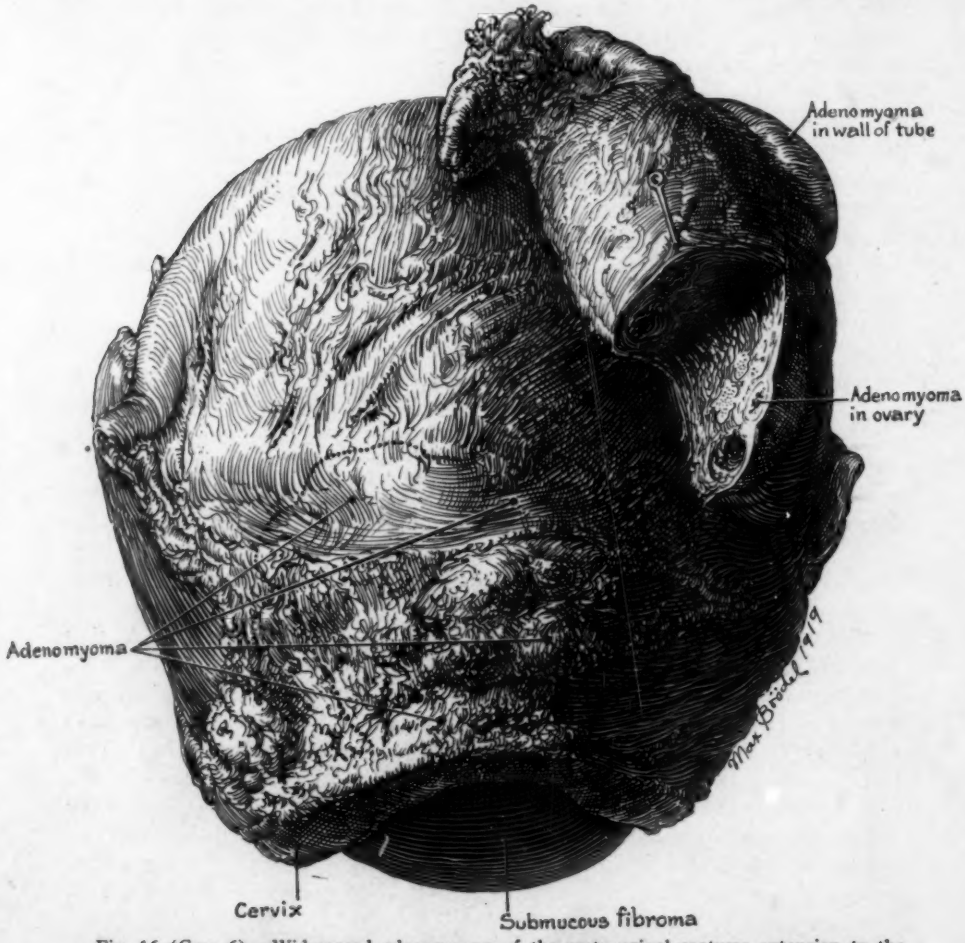


Fig. 16 (Case 6).—Widespread adenomyoma of the rectovaginal septum; extension to the surface of the right ovary and tube. The supravaginally amputated uterus was 13 cm. long and 11 cm. broad. Its anterior surface was smooth, its posterior surface covered by adhesions. Occupying the posterior surface of the cervix and extending well up on the body of the uterus was a diffuse and hard growth. This consisted of typical adenomyoma (Figs. 17, 18 and 19). The right tube and ovary formed one large solid mass, and on the surface of both tube and ovary was typical uterine mucosa (Figs. 20 and 21). This is the most widespread distribution of an adenomyoma of the rectovaginal septum that I have ever seen.

matter of fact, the left tube and ovary and the sigmoid flexure formed one solid mass.

The operation was begun by separating some loops of bowel from the pelvis, then the left round ligament was cut; the left tube and ovary were clamped off at the uterus and left temporarily in place. The bladder was pushed down

Fig. 17 (Case 6).—Adenomyoma of the rectovaginal septum. This section is from the cervix of the uterus seen in Figure 16. To the left is normal cervical mucosa, to the right we see islands of uterine mucosa from the rectovaginal septum. The area *a* has been magnified and is shown in Figure 18.

and the right round ligament was cut, the right ovarian vessels were then clamped and cut. After this procedure, it was found possible to lift the uterus well up, and we then realized that without doubt we were also dealing with an adenomyoma of the rectovaginal septum. Dissection was gradually carried down on the posterior surface of the cervix as far as possible, and a supravaginal amputation performed. Better exposure could now be obtained, and the stump of the cervix was dissected free. The rectum was densely adherent to the hard mass occupying the lower and posterior part of the uterus, the posterior part of the cervix and the adjacent rectovaginal septum. During manipulation a little dark blood escaped from the rectovaginal septum. To

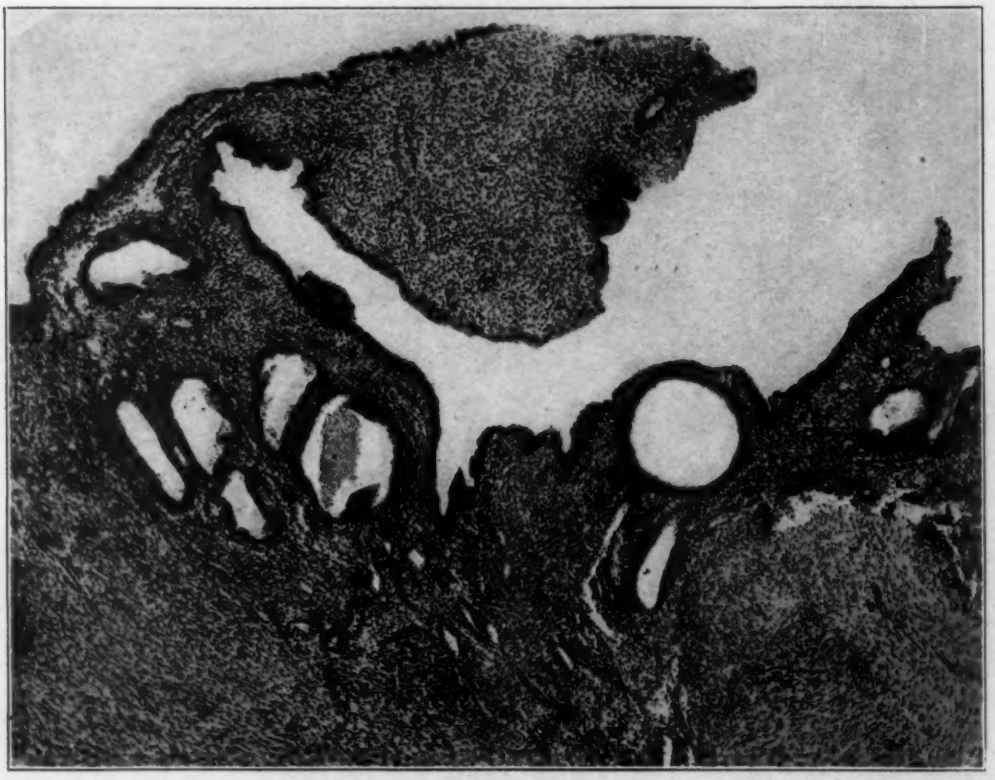


Fig. 18 (Case 6).—This picture is an enlargement of the area *a* in Figure 17. One sees numerous uterine glands surrounded by the typical stroma of the mucosa. A few of the glands are dilated. In the upper part of the picture is an area of characteristic stroma covered over by one layer of cylindric epithelium.

have removed entirely the diffuse growth of the rectovaginal septum would have been an impossibility. As it was, it was one of the most difficult hysterectomies I ever attempted. The ureters were not exposed on either side, but they could be seen through the pelvic peritoneum; they were well removed from the point where the uterine vessels were controlled.

The cut edge of the vaginal mucosa was then controlled all the way round, and then the broad ligaments were obliterated as far as possible. Notwithstanding our attempts to leave a smooth surface, a small amount of raw area still remained in the culdesac. Two cigaret drains were placed in the pelvis

and brought out through the vagina. The abdomen was then closed in the usual manner. The patient lost a considerable amount of blood during the operation but left the table in good condition.

She was discharged, June 1, 1919. There was no induration in the pelvis and she felt well.

We shall watch the subsequent history in this case with a good deal of interest as some of the adenomyomatous growth was of necessity left adherent to the rectum.

Examination of Specimen (Gyn. Path. No. 25003).—The specimen consists of the enlarged uterus with its detached cervix and of the appendages from both sides

The supravaginally amputated uterus is 13 cm. long and 11 cm. in its anteroposterior diameters. The anterior surface of the uterus is smooth, the posterior surface at the fundus is covered by shaggy adhesions. The greater

Fig. 19 (Case 6).—Adenomyoma of the rectovaginal septum. This is a section from the adenomyoma of the rectovaginal septum shown in Figure 16. The uterine mucosa is unusually abundant, forming fully half of the section. Even with the very low power it will be noted that many of the glands show hypertrophy.

part of the posterior surface over an area approximately 7 cm. from above downward and 12 cm. from side to side presents a rough and ragged appearance. This is the area that will prove to be of the greatest interest, the appearance being due to a widespread adenomyoma occupying the posterior surface of the uterus and cervix (Fig. 16).

The increase in size of the uterus is in large measure due to the presence of a submucous myoma 10 cm. in length. This projects into the uterine cavity from the posterior wall. The anterior wall of the uterus varies from 1.5 to 2 cm. in thickness, and the mucosa from 1 to 7 mm. The mucous membrane over the surface of the submucous myoma is very thin, in most places being not over 0.5 mm. thick.

The widespread raw area which occupies the greater part of the posterior surface of the uterus has a very ragged appearance. As noted from the description of the operation, this area had literally to be cut away from the rectum. On incising the raw area, one notes a coarse striation of the tissue, and at various points are small brownish specks. Histologic examination will show that this is adenomyomatous tissue.

The lower portion of the cervix was removed after the fundus had been taken away. The vaginal portion of the cervix shows some eversion of the cervical mucosa.

Right Side: The tube and ovary form a conglomerate mass which has been densely adherent to the side of the uterus as well as to the surrounding structures. Notwithstanding this the fimbriated end of the tube is patent and

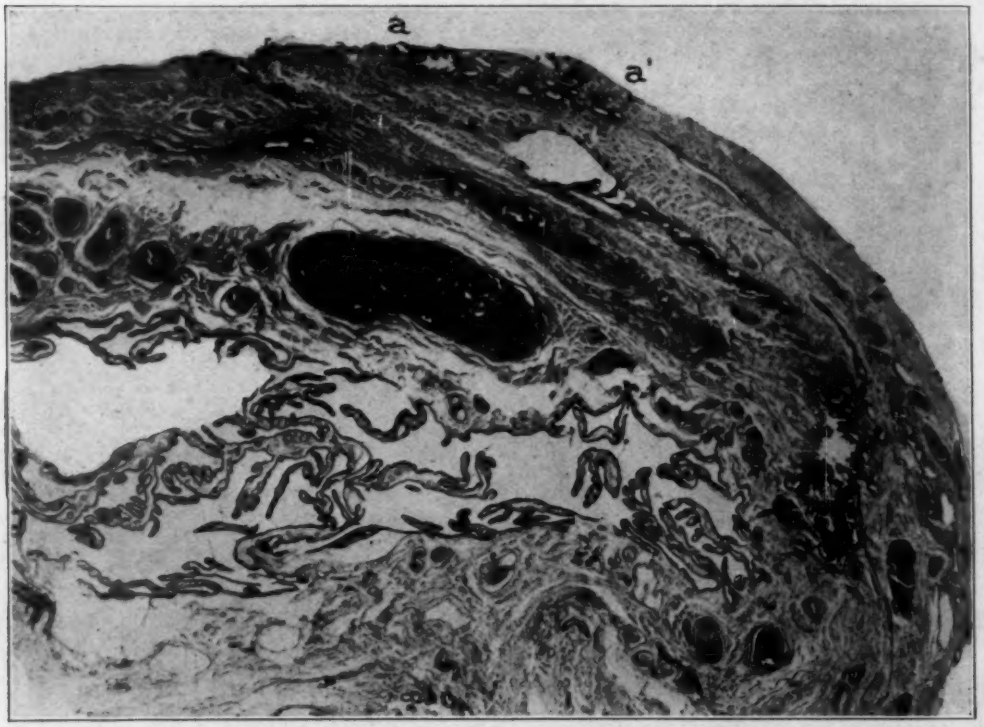


Fig. 20 (Case 6).—Extension of an adenomyoma of the rectovaginal septum to the surface of the adherent fallopian tube. The gross appearance of the tube is shown in Figure 16. The folds of the tube look relatively normal. The solid black areas are blood vessels. On the surface of the tube at a-á is an area of typical uterine mucosa. It really looks as if the widespread adenomyoma of the rectovaginal septum has literally flowed over on the surface of the tube.

appears relatively normal. The tubo-ovarian mass measures 10 cm. in length and at one point reaches a diameter of 5 cm. It is impossible to trace the continuity of the tube in its middle portion where it is intimately attached to the ovary and is covered by adhesions. The ovary contains at least two small corpora lutea cysts.

Left Side: The appendages form an inseparable mass, 6 cm. long and about 4 cm. in diameter. They are embedded in adhesions, but the fimbriated end of the tube is patent.

Fig. 21 (Case 6).—Uterine mucosa on the surface of the ovary in a case of adenomyoma of the rectovaginal septum. For the gross appearance of the ovary see Figure 16. The miniature uterine cavity on the surface of the right ovary is represented by *a*. The lining mucosa resembles in every particular that of the body of the uterus. Some of the glands show hypertrophy. The mucosa of the adenomyoma of the rectovaginal septum seems to have overflowed to the surface of the adherent ovary. The same condition was noted on the surface of the corresponding tube (Fig. 20).

Histologic Examination.—Sections from the cervical mucosa show that it is normal (Fig. 17). Sections from various portions of the large raw area on the posterior surface of the body of the uterus and cervix present an amazing picture (Figs. 17, 18 and 19). The tissue consists in large measure of nonstriped muscle, and scattered everywhere throughout this are tremendous areas of perfectly normal looking uterine mucosa. So abundant is the mucosa in many places that it forms at least one half or two thirds of the section. This mucous membrane in many places shows a tendency toward hypertrophy (Fig. 19). Its stroma shows a considerable amount of hemorrhage, and here and there a gland is dilated reaching a millimeter or more in diameter. This is the most widespread distribution of an adenomyoma on the posterior surface of the uterus that I have ever seen.

The myoma occupying the posterior wall of the uterus and projecting into the uterine cavity shows much hyaline degeneration.

Sections from the right uterine cornu show that the tube at this point is perfectly normal, but sections further out, although showing a normal mucosa, reveal typical areas of uterine mucosa on the surface of the tube (Fig. 20). One gathers the impression that the uterine mucosa from the diffuse adenomyoma on the posterior surface of the cervix and uterus has overflowed upon the adherent tube.

On the surface of and intimately attached to the right ovary is a miniature uterine cavity (Fig. 21). The glands of its mucosa show a moderate hypertrophy. Other sections from the same ovary show a diffuse adenomyoma intimately blended with the ovarian tissue, so intimately attached that no line of demarcation can be detected. It must be remembered, however, that this ovary was firmly glued to and continuous with the diffuse adenomyoma occupying the posterior surface of the uterus.

Case 7 (Septum Case 15).—*Adenomyoma of the rectovaginal septum* (Figs. 22 and 23).

History (Gyn. No. 24984).—C. B., aged 36, white, entered the Johns Hopkins Hospital, June 12, 1919, complaining of pain in the left lower abdomen at the menstrual period. She also had severe headaches. The menses began at 13, were regular until six months ago when they appeared three times in a month; the last period was on June 7, the one previous on May 28. During the last two months the pain had been severe in the left lower abdomen. She gave no history of rectal bleeding at the menstrual period.

Examination.—On pelvic examination, the cervix was found low in the vagina. The body of the uterus had dropped back, was irregular and nodular in outline. In the left side of the pelvis was a movable, cystic, rather tense mass about 8 cm. in diameter.

Operation.—On examination under anesthesia in addition to the above findings, a small cystic mass could be felt on the right. June 14, the abdomen was opened and two cysts with rather opaque looking walls were seen in the pelvis. One lay up in under the left broad ligament, the other occupied the floor of the culdesac; both contained dark chocolate-colored fluid, in other words, there was a corpus luteum cyst on each side. The cysts were resected and a small piece of ovary was left on both sides. After removal of the cyst, there still remained a small adherent mass between the cervix and rectum, and there was no doubt that an adenomyoma of the rectovaginal septum existed. The ureters were isolated, the uterus freed on all sides and the vagina cut across. A small amount of adenomyomatous tissue was left adherent to the rectum. Near the completion of the operation, it was found that the left tube

and ovary had a very poor blood supply, and for this reason they were removed. The appendix, which was very long, was also removed. A drain was laid in the pelvis and brought out through the vagina. The abdomen was then closed. A considerable amount of blood was lost during the operation. The patient left the table in fair condition. She was discharged, July 5, 1919, in good condition.

Examination of Specimen (Gyn. Path. No. 25120).—The specimen consists of the uterus and of the much mutilated appendages together with the appendix.

The uterus is 11 cm. long, 6 cm. broad and 4 cm. in its anteroposterior diameters (Fig. 22). The anterior surface is smooth. The posterior surface almost to the top of the fundus is covered by adhesions. Springing from the posterior surface of the cervix is a raised hard area 2.5 by 2 cm. The tissue here is exceptionally hard, and on section it presents a brownish black appearance. It extends into the posterior cervical wall nearly 1 cm. and spreads

Fig. 22 (Case 7).—Adenomyoma of the rectovaginal septum. The posterior surface of the fundus is partially covered by adhesions. Springing from the posterior part of the cervix near the vaginal attachment is a well defined adenomyoma 2.5 by 2 cm. For the histologic picture, see Figure 23.

out like the broad roots of a tree. It also encroaches slightly on the posterior vaginal wall. The mucosa of the vaginal portion of the cervix is somewhat everted. The mucous membrane lining the cervical canal and the cavity of the uterus presents the usual appearance.

On account of mutilation it is impossible to tell which are the right and which the left appendages. One ovary has been converted into a thin-walled cyst, 7 cm. in diameter. The inner surface of this presents a dirty chocolate-colored appearance. It is a corpus luteum cyst. A portion of the other ovary is covered by dense adhesions. It contains a corpus luteum cyst, 4 cm. in diameter. Accompanying the specimen is one fallopian tube which is perfectly normal. As noted from the history, one tube and part of one ovary were left

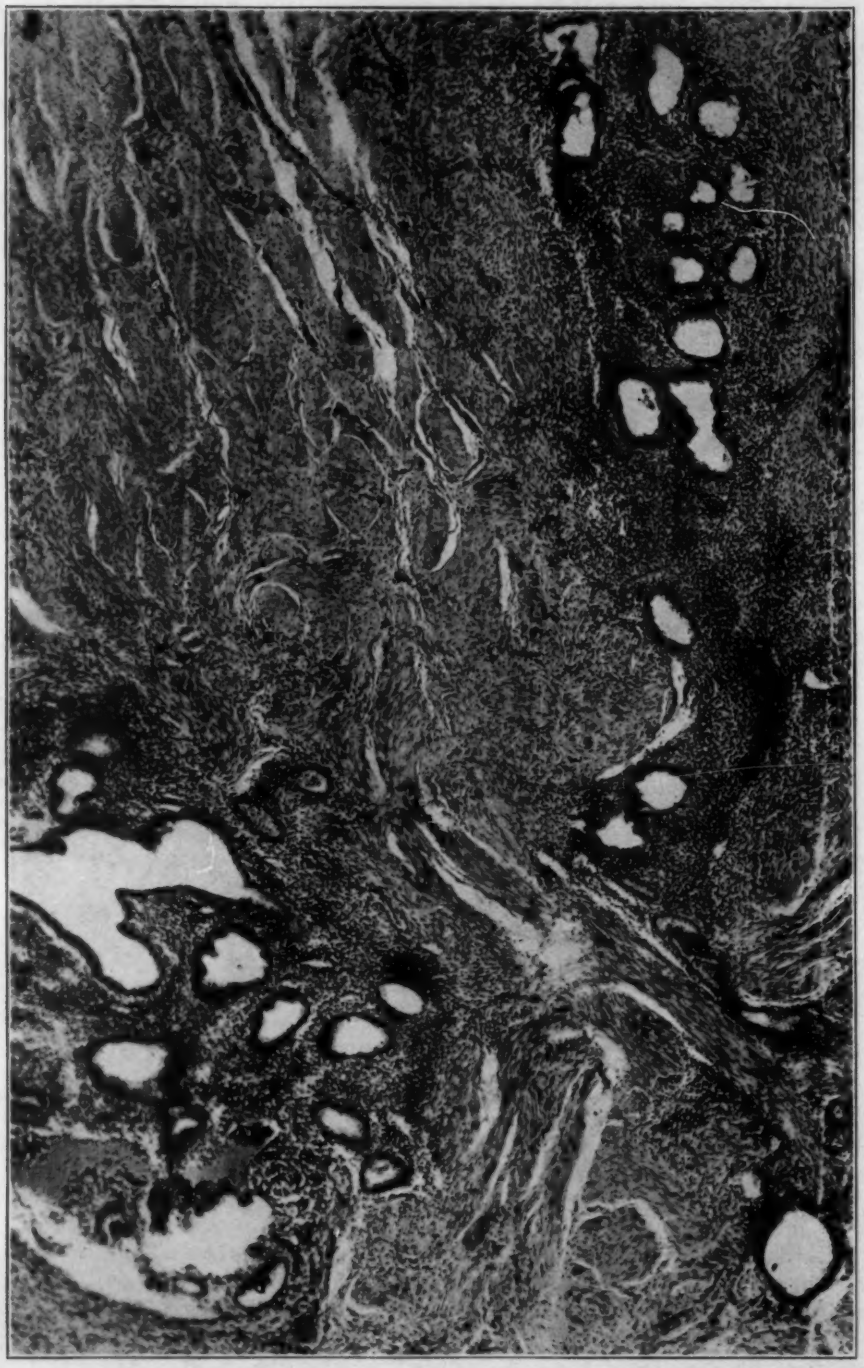


Fig. 23 (Case 7).—Adenomyoma of the rectovaginal septum. For the gross specimen, see Figure 22. The matrix of the growth is made up of nonstriped muscle and fibrous tissue. Occupying fully one third of the field are areas of typical uterine mucosa. Some of the glands are dilated. Here and there a gland lies in direct contact with the muscle.

in place. We had in this case corpora lutea cysts on both sides, and these were covered by adhesions while both tubes were normal.

The appendix is very hard, 9 mm. in diameter. The lumen of the appendix is not over 1 mm. in diameter.

Histologic Examination.—The cervical glands present the usual appearance. The mucosa lining the body of the uterus shows some small round cell infiltration in the superficial layers. The growth on the posterior surface of the cervix consists of nonstriped muscle and fibrous tissue. Scattered throughout it are large and small islands of uterine mucosa (Fig. 23). The stroma of this mucosa shows a considerable amount of hemorrhage. Here and there a uterine gland lies in direct contact with the muscle.

The picture is that of a typical adenomyoma of the rectovaginal septum.

Fig. 24 (Case 8).—Multiple uterine myomas; adenomyoma of the rectovaginal septum. The specimen is viewed from behind. Scattered over the posterior surface of the uterus are several small myomas, and projecting into the left broad ligament is a myoma 3.5 by 2.5 cm. Occupying the posterior part of the cervix is a rather extensive adenomyoma. This was densely adherent to the rectum which had been drawn up. For the histologic appearance of the adenomyoma, see Figure 25.

CASE 8 (Septum Case 16).—*Adenomyoma of the rectovaginal septum; small multiple uterine myomas* (Figs. 24 and 25).

History (C. H. I. No. 22465).—C. W., aged 36, was referred to me by Dr. Carlton M. Cook, Oct. 9, 1919.

She began to menstruate at 14, was regular; the flow was free and lasted from six to seven days. It was formerly painful for the first two days but now the pain persisted throughout the entire period and the patient had to remain in bed. Her last period ended a few days ago. It had persisted for ten days.

Twelve years ago she had an abdominal operation; several fibroids were removed, one ovary and part of the other were also taken away.

The patient has been worse since she had influenza in October, 1918.

Examination.—The patient was admitted to the Church Home and Infirmary October 9, and operated on Nov. 4, 1919. On examining this patient under anesthesia, I felt a nodule, about 1 cm. in diameter, just posterior to the cervix and was instantly reminded of an adenomyoma of the rectovaginal septum. On the left side was an area of thickening, approximately 2 by 3 cm. As there were evidently many adhesions, a definite diagnosis could not be made.

Operation and Result.—I made a median incision and found a few omental adhesions on the anterior abdominal wall. The left tube and ovary had been removed at a previous operation. The right ovary was densely adherent to the pelvic floor and also to an epiploic appendage. We decided that a removal of the uterus was indicated, more particularly as the cervix was adherent to the anterior surface of the rectum. The rectum was also drawn upward. We removed the uterus from left to right, amputating through the cervix and removing the left tube and ovary.

Fig. 25 (Case 8).—Adenomyoma of the rectovaginal septum. For the gross picture, see Figure 24. The muscular growth is very dense, the glands few and far between. In the upper part of the picture is a definite gland lying in direct contact with the muscle, and the surface at a is covered by one layer of cylindric epithelium.

After removing the uterus, I took out the cervix and it was necessary literally to cut the posterior vaginal wall and the cervix away from the rectum. There was just the slightest area of thickening on the anterior rectal wall.

After controlling all oozing, we examined the right ureter and found it normal. The left ureter could not have been located without a great deal of dissecting. The appendix was curled on itself and adherent. It was also removed. Two drains were left in the pelvis and brought out through the vagina.

The patient left the hospital in excellent condition on Nov. 24, 1919.

Examination of Specimen (Gyn. Path. No. 25477).—The cervix and body of the uterus when put together give a combined length of 8 cm. (Fig. 24). The uterus is 6 cm. broad and 4 cm. in its anteroposterior diameters. The anterior surface of the uterus is smooth, but nearly the entire posterior surface is covered by adhesions. Projecting from the posterior surface, high up, is a pedunculated bean-shaped myoma, 1.5 cm. long. There are also a few other minute myomas scattered over the surface of the uterus. Attached to the left side of the cervix and extending into the broad ligament is a myoma,

3.5 by 2.5 cm. Projecting from the center of the cervix posteriorly is a small raised area of thickening, about 1 cm. in diameter. This is where the rectum was attached to the cervix. The cavity of the uterus contains a pedunculated submucous myoma, 2 cm. in diameter. The thickening noted on the posterior wall of the cervix is hard and contains a few chocolate-colored areas.

Histologic Examination.—Sections from the cervix show that the mucosa is normal. The growth on the posterior surface of the cervix consists of non-striped muscle and fibrous tissue. In the outlying portions it is interesting to

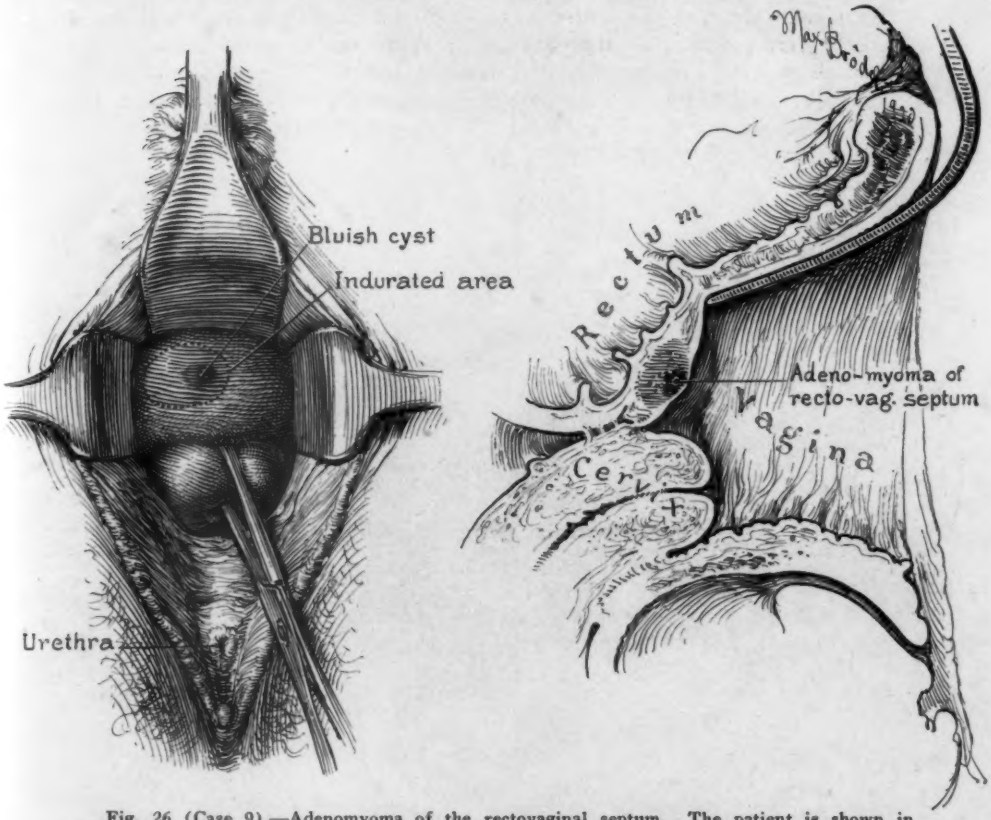


Fig. 26 (Case 9).—Adenomyoma of the rectovaginal septum. The patient is shown in the knee-chest posture. Just behind the cervix and slightly to the left of the median line is a relatively globular nodule about 1.5 cm. in diameter. In this nodule were two bluish black cysts, only one of which could be clearly seen. The relation of the adenomyoma to the cervix and rectum is clearly indicated in the picture to the right. Although no microscopic examination has been possible, still the diagnosis is certain.

see the manner in which the diffuse myomatous growth is gradually replacing the adipose tissue. Here and there in the diffuse growth is a uterine gland usually lying in direct contact with the muscle (Fig. 25). Some of the growth has, as was noted at operation, been left attached to the rectum.

Case 9 (Septum Case 17).—*Adenomyoma of the rectovaginal septum* (Fig. 26).

History.—Mrs. E. B. H., aged 36, referred to me by Dr. Arthur Wegefarth, entered the Church Home and Infirmary Nov. 1, 1919 (No. 22461). I had operated on this patient in 1917 for appendicitis. In August, 1919, while at

dinner, she was taken with sharp, excruciating pain beneath the right costal margin, and the pain radiated to a point just beneath the right shoulder blade. She was almost drawn double. This attack was followed by nausea and vomiting, and the pain was relieved only by morphin. Since then she had had eight similar attacks. The patient had been married twenty years and had one child, nineteen years ago. She also complained of pain in the left lower abdomen.

Examination.—On making a pelvic examination, under anesthesia, I found the uterus normal in size. The cervix was normal, but just posterior and a little to the left was a rather globular nodule 1.5 cm. in diameter (Fig. 26). This seemed fixed to the cervix posteriorly, and on inspection it was found that projecting from the vaginal vault at this point were two bluish black cysts, about 2 mm. in diameter. On rectal examination, the nodule was made out much more clearly. It was directly beneath the mucous membrane, but the mucosa had not become adherent. It was a definite adenomyoma.

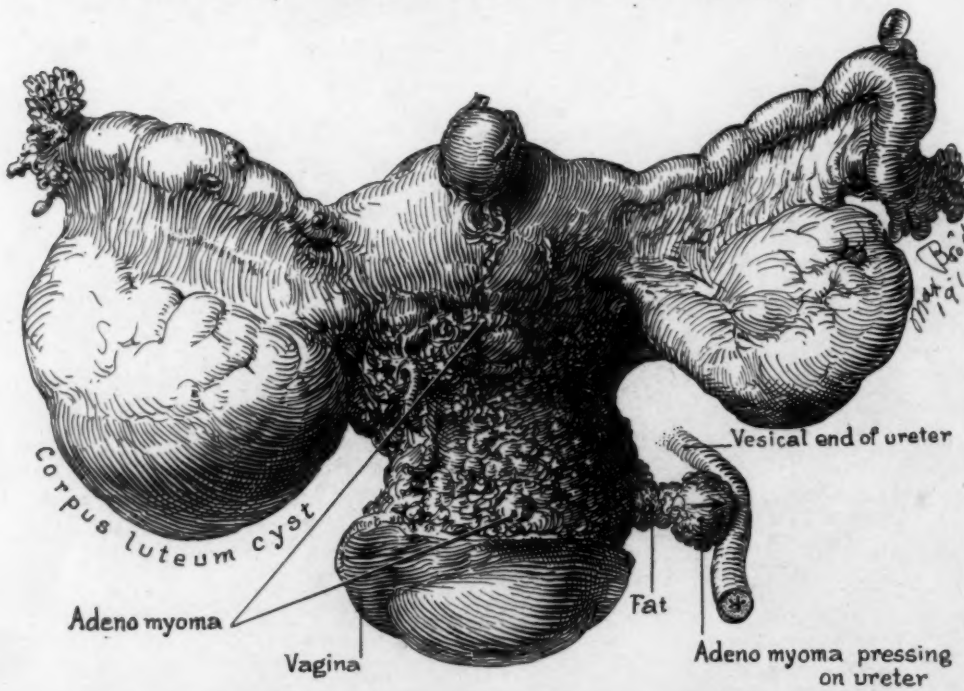


Fig. 27 (Case 10).—Adenomyoma of the rectovaginal septum; discrete and independent adenomyoma in the right broad ligament pressing on and partially obstructing the ureter. Springing from the top of the uterus is a small myoma, and attached to the posterior surface of the uterus are a few adhesions. Occupying the posterior part of the cervix and extending upward is a diffuse adenomyoma. The right tube and ovary are normal. The left tube is normal, but the ovary contains a corpus luteum cyst. In the right broad ligament is a small discrete nodule pressing on the right ureter. It is also an adenomyoma. For the histologic picture of the adenomyoma of the rectovaginal septum, see Figure 28; for that of the broad ligament nodule, Figure 29.

Operation and Result.—Nov. 4, 1919, I operated and as the patient was not complaining sufficiently of the pelvic condition, and as she had gallstones, I let the adenomyoma alone. I made a right rectus incision and exposed the gallbladder which contained a large number of small stones, the greater number of which formed two conglomerate masses, each about 1.5 cm. in diameter. Some of the smaller stones were in the cystic duct. We removed the stones

and drained the gallbladder. The patient was discharged much relieved, Nov. 29, 1919.

A few weeks later she developed a pelvic abscess which opened spontaneously into the vagina, and since then she has been perfectly comfortable. It may be necessary to remove the adenomyoma at a later date.

CASE 10 (Septum Case 18).—*Adenomyoma of the rectovaginal septum; discrete adenomyoma in the right broad ligament pressing on and partially obstructing the right ureter* (Figs. 27, 28 and 29).

History.—Miss R. M., aged 42, was referred to me by Dr. Christian Deetjen on Feb. 27, 1919, complaining of pain in the left lower abdomen. This had been more or less constant for the last ten years and had been severe for four years. The patient had pneumonia ten years ago followed by empyema. She was admitted to the Church Home and Infirmary, Oct. 20, 1919 (No. 22402).

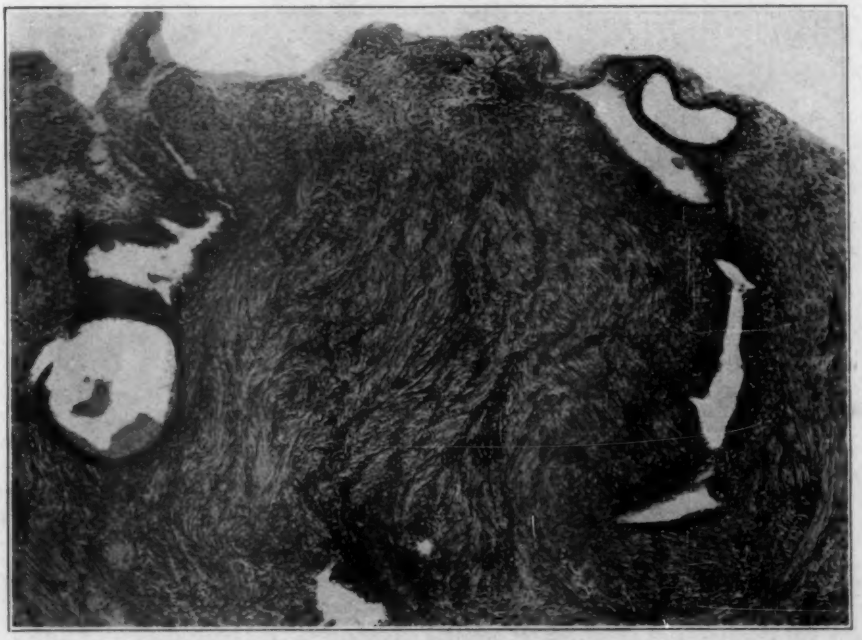


Fig. 28 (Case 10).—Adenomyoma of the rectovaginal septum. The gross specimen is shown in Figure 27. Some of the glands are surrounded by the characteristic stroma, others lie in direct contact with the muscle.

At that time a small cyst could be felt in the left side of the pelvis. Dr. Hiram Fried, the resident, felt that there might be some trouble with the ureters and suggested their catheterization. A distinct narrowing was felt on the right side not far distant from the bladder. Dr. Guy L. Hunner confirmed this finding. The right ureter was dilated on several occasions, and we finally operated on November 8.

Operation and Result.—On opening the abdomen, I found a corpus luteum cyst, 4 cm. in diameter, on the left side. This was somewhat adherent.

The rectum had grown fast to the posterior surface of the cervix and at this point the tissues presented a yellowish brown, rusty appearance. It was perfectly evident that we were dealing with an adenomyoma. We performed

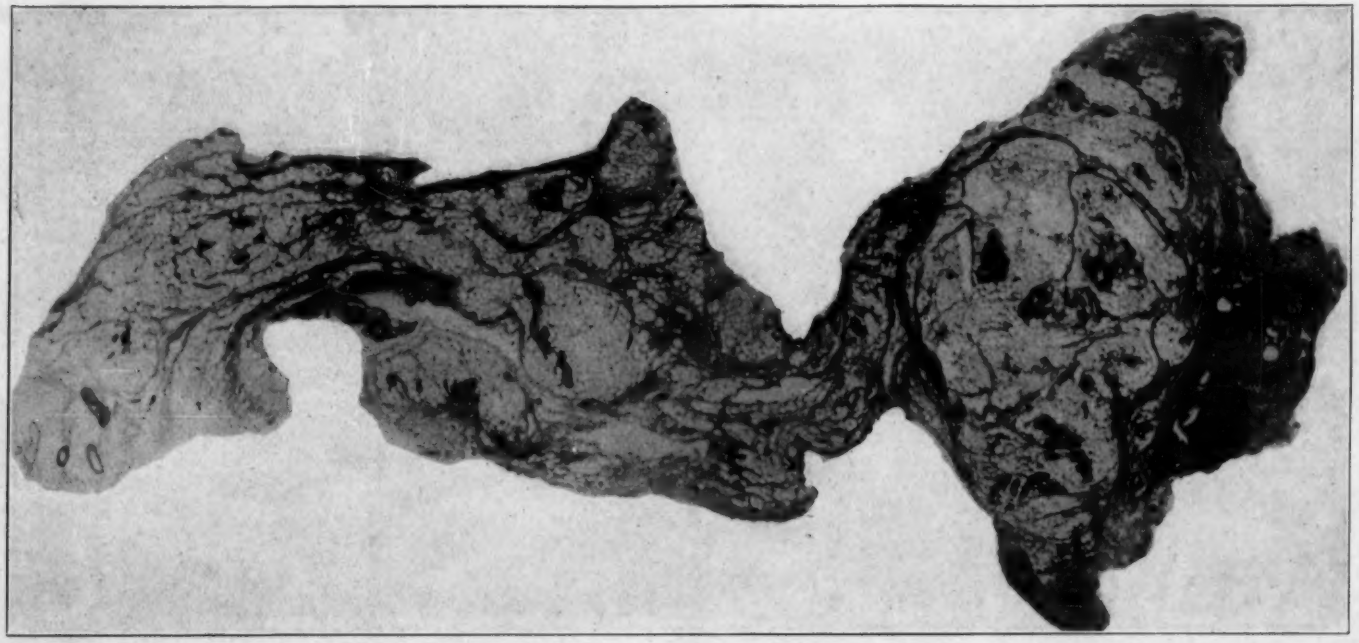


Fig. 29 (Case 10).—Discrete adenomyoma of the right broad ligament pressing on and partially obstructing the ureter. For the appearance at operation, see Figure 27. At the left, where this nodule was attached to the right side of the cervix, most of the tissue consists of fat. As we pass toward the right the adipose tissue is found to be replaced in part by connective tissue. At the extreme right the tissue consists of nonstriped muscle and fibrous tissue, and scattered throughout it are a moderate number of glands resembling those of the uterine mucosa.

a complete abdominal hysterectomy. The posterior vaginal wall separated from the rectum with some difficulty, but after removal of the uterus and upper vagina the bowel showed only a slight thickening. The rectovaginal growth had extended out into the right broad ligament. After its removal we could still feel a nodule far out in the broad ligament. This was 1 cm. in diameter, encroached markedly on the right ureter and had given rise to the obstruction that had been noted by Dr. Fried in his catheterization of this ureter (Fig. 27). I dissected out the ureter, drew it to one side and removed the nodule. Two drains were left in the pelvis and brought out through the vagina.

The patient had an uneventful convalescence and was discharged Nov. 30, 1919.

Examination of Specimen (Gyn. Path. No. 25486).—The uterus is 7 cm. long, 4 cm. broad and 3 cm. in its anteroposterior diameter. Anteriorly it is smooth. The posterior surface is covered by adhesions. At the fundus posteriorly is a myoma, 1.5 cm. in diameter, and below this a minute myoma. Springing from the posterior surface of the cervix is a nodular thickening, 1.5 cm. in diameter, and extending off from this point is the nodule that was pressing on the right ureter. The uterine walls vary from 1 to 1.5 cm. in thickness, and in the fundus the muscle presents a very coarsely striated appearance reminding one somewhat of an adenomyoma. The uterine mucosa is rather thin.

Right Side: The tube and ovary are normal.

Left Side: The ovary contains a corpus luteum cyst, 3 cm. in diameter. The ovary is covered by a few adhesions.

Histologic Examination.—The vaginal portion of the cervix presents the usual appearance. The cervical mucosa is gathered into folds and tends to form small polypi. A few of the glands are dilated, but the cervical mucosa as a whole is relatively normal.

The section from the growth on the posterior surface of the cervix contains a young myoma, 3 mm. in diameter. The diffuse growth consists of nonstriped muscle and fibrous tissue. Scattered throughout it are small areas of uterine mucosa (Fig. 28). Few of these areas contain more than two uterine glands accompanied by the characteristic stroma. Here and there is a dilated gland.

The nodule from the right broad ligament, the one that was pressing on the right ureter, consists for the most part of adipose tissue (Fig. 29). Scattered throughout the fat are a good many large blood vessels and passing off from these are young strands of connective tissue which tend to separate the individual fat globules from one another. The outer end of the growth consists of an irregular mass of fibrous tissue and nonstriped muscle. This fibromuscular mass sends prolongations into the surrounding fat and in the nodule itself some fat still persists. Scattered throughout the muscular tissue are uterine glands occurring singly or in groups. When in groups, they are surrounded by the characteristic stroma which shows some hemorrhage. When singly, they lie in direct contact with the muscle. Some of the glands are dilated.

This is a case of adenomyoma of the rectovaginal septum. There is also a discrete adenomyoma apparently independent of the uterus and pressing on the right ureter.

The preceding cases have come under my individual care. The following case of adenomyoma of the rectovaginal septum is a rather advanced one and is well worth recording. The operation was per-

formed at the Hebrew Hospital by Dr. Alfred Ullman, and the specimen was sent to me for examination. The history was furnished me by Dr. E. H. Teeter.

CASE 11.—*Adenomyoma of the rectovaginal septum.*

History.—M. H., aged 46, was admitted to the Hebrew Hospital, April 24, 1919, complained of bleeding for nine weeks, and that she felt very sore and tired all over. She had not had any previous illness. Her menses began at 13, were regular, and usually lasted from seven to nine days. The flow was always excessive and was accompanied by pain in the left lower abdomen for three days. In June, 1918, her menses stopped for three months and then there was a little bleeding for a couple of days. The bleeding soon returned and had persisted for the last nine weeks. It had been very severe. On vaginal

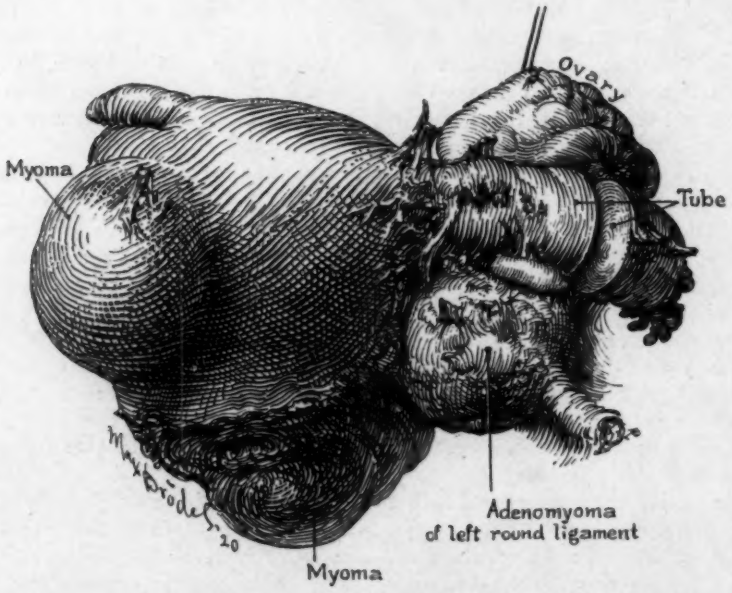


Fig. 30 (Case 12).—Adenomyoma of the left round ligament. The uterus contains several small discrete myomas. The left round ligament near its uterine attachment contains a spherical myoma, 1.5 cm. in diameter. This was adherent to the tube at its inner end. Lying between the round ligament nodule and the tube and adherent to both was a loop of small bowel. The left tube is unusually thick. Its fimbriated end is constricted but open. The tube on histologic examination showed slight inflammation. The ovary contained a corpus luteum. It was slightly adherent. For the low power picture of the adenomyoma of the round ligament, see Figure 31; for the higher power, Figure 32.

examination, April 25, Dr. Teeter made the following note: "Vaginal outlet somewhat relaxed, cervix normal. The uterus and cervix are tied hard and fast and cannot be moved. The uterus itself is normal in size. Just posterior to the cervix is a growth in the vaginal vault causing puckering of the vaginal mucosa. This growth is hard and is glued fast to the rectum. On rectal examination, the mass is found to be adherent to the rectum, but the growth does not involve the rectal mucosa."

There was a profuse bloody discharge from the uterus and Dr. Teeter at once made a diagnosis of adenomyoma of the rectovaginal septum.

A complete abdominal hysterectomy was performed by Dr. Alfred Ullman on April 26, and the patient was discharged May 20.

Examination of Specimen (Gyn. Path. No. 25513).—The uterus is 9 cm. long, 6 cm. broad and 5 cm. in its anteroposterior diameters. The anterior surface is smooth as is also the posterior surface. Just anterior to the insertion of the right tube is a myoma, 6 mm. in diameter .

Springing from the posterior surface of the cervix and extending over to the right side and also involving the posterior vaginal wall is a hard, irregular

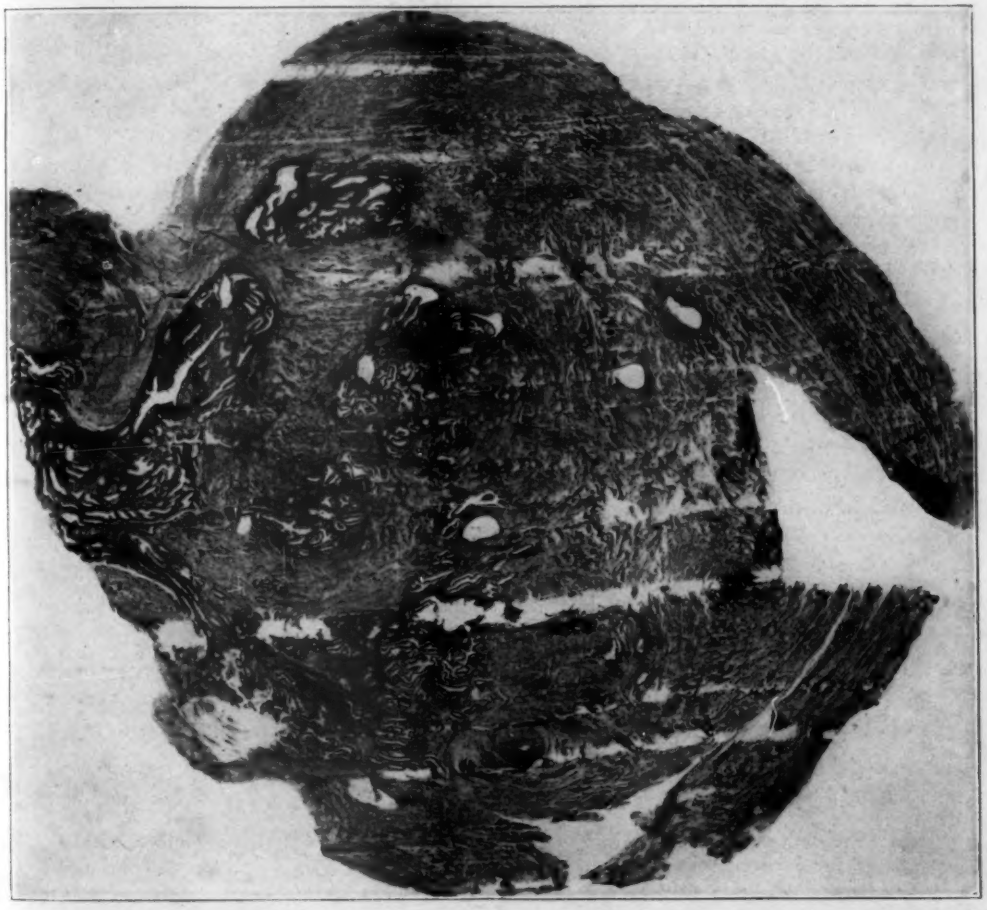


Fig. 31 (Case 12).—Adenomyoma of the round ligament. This is a low power photomicrograph of the round ligament nodule seen in Figure 30. Nearly one half of the tissue consists of islands of perfectly normal uterine mucosa. For the high power, see Figure 32.

growth, 4.5 cm. broad and 2.5 cm. from above downward. It is exceedingly firm and where it involves the vagina are five or six dark brown areas of discoloration. These vary from 1 to 2 mm. in diameter. On section, the growth reminds one of myomatous tissue, and scattered throughout it are a few irregular cavities filled with a yellowish brown or yellow material. The cavity of the uterus looks normal.

Histologic Examination.—Sections through the vaginal portion of the cervix and also through the adjoining vaginal wall reveal a normal mucosa. Beneath the vaginal mucosa the dense stroma contains isolated uterine glands. The small chocolate-colored cysts noted beneath the vaginal mucosa are filled with blood. They are lined with one layer of cylindric epithelium, and projecting into one of the cysts is a small knoblike elevation of typical stroma of the endometrium of the body of the uterus. Some of these cysts lie in direct contact with the surrounding muscular and fibrous tissue, others are separated by a definite endometrial stroma.

The growth on the posterior surface of the cervix and involving the posterior vaginal wall consists of nonstriped muscle and fibrous tissue. Here and there small areas of adipose tissue have been enveloped. Scattered throughout the growth are isolated uterine glands and groups of glands. Nearly all of these glands are surrounded by the characteristic stroma, and some of them are filled with blood.

The case is one of adenomyoma of the rectovaginal septum. It is in just such a case that we would later expect to find vaginal polypi had the operation been delayed for a year or two.

ADENOMYOMA OF THE UTERINE HORN OR FALLOPIAN TUBE

In addition to the diffuse adenomyoma of the uterus, one finds another variety of adenomyoma in this organ. These are the small adenomyomatous nodules noted in one or both uterine horns. They vary from a few millimeters to about 2 cm. in size and are often associated with an old inflammatory process in the tubes. These growths usually contain many isolated glands embedded in nonstriped muscle and inflammatory tissue. The glands usually lie in direct contact with the muscle and are devoid of the characteristic stroma. Adenomyoma of the uterine horn can, as a rule, hardly be looked on as a distinct clinical entity, but rather, I think, as part of the end-result of a mild inflammatory process.

In a case (Gyn.-Path. No. 25515) in which we had a bicornate uterus, and a most extensive adenomyoma of the right cornu, the left tube 2 cm. beyond the uterine horn was 1 cm. in diameter. On histologic examination, it was found to be the seat of an adenomyoma. Some of the glands lay in direct contact with the muscle, others were surrounded by the typical stroma of the uterine mucosa. I know of no other tube presenting such a picture.

ADENOMYOMA OF THE ROUND LIGAMENT[4]

In 1896, it fell to my lot to record the first growth of this character. Since then quite a number have been noted. Somewhere along the course of the round ligament, usually near the external ring, a nodule

4. Cullen, T. S.: Adenomyoma of the Round Ligament, Bull. Johns Hopkins Hosp. **7**:112 (May-June) 1896; Further Remarks on Adenomyoma of the Round Ligament, Bull. Johns Hopkins Hosp. **9**:142 (June) 1898; Adenomyoma of the Round Ligament, and Incarcerated Omentum in an Inguinal Hernia, Together Forming One Tumor, Surg., Gynec. & Obst. **22**:258 (March) 1916.

one or more centimeters in diameter is detected. On going carefully into the history, it will be noted that this growth swells perceptibly at the period. One patient was sent to me on the assumption that a hernia existed, but even in this case in the history it was recorded that the swelling was more painful and more prominent at the period.

With the gradual increase in size of the nodule it may become intimately blended with the fascia. In my second case the diagnosis was easily confirmed at operation, even before any microscopic examination had been made. The surrounding fascia had imbibed a large amount of golden yellow pigment—the remnant of old menstrual blood.

Some of these growths can be removed very readily, others, however, in time may become so intimately blended with the surrounding structures that they must be literally cut away. On histologic examination, they are found to be made up of nonstriped muscle, fibrous tissue, and the characteristic uterine glands. Strands of fibrous tissue and nonstriped muscle spread out into the surrounding adipose tissue.

Just lately (April, 1920) we have encountered another case of adenomyoma of the round ligament in our clinic in the Johns Hopkins Hospital (Fig. 30).

Case 12 (Gyn. No. 25776).—*History.*—E. S., aged 36, white, was admitted to the Johns Hopkins Hospital on April 1, 1920, complaining of dysmenorrhea and of bleeding between periods. She had been married four years, but had had no children.

Examination.—On pelvic examination, the outlet was found to be relatively intact. Protruding from the cervix was a small polyp. The body of the uterus was in retroposition, was irregular and apparently contained five or six small myomatous nodules. High up in the left vaginal fornix was a mass, 2 or 3 cm. in diameter.

Operation and Result.—April 3, 1920, Dr. Leo Brady operated and found the uterus in retroposition. It contained several small myomas. In the left round ligament near the uterus was a nodule nearly 2 cm. in diameter. The tube was adherent to this and also to a loop of small bowel. The right appendages were free. After the loop of bowel had been freed, a supravaginal hysterectomy was performed. The patient made a satisfactory recovery except for a slight elevation of temperature during the first week following operation when there was a friction rub. This was thought to be due probably to a lighting up of an old pleurisy. She was discharged in good condition on April 21, 1920.

Examination of Specimen (Gyn. Path. No. 25850).—The uterus, which had been amputated through the cervix, measures 5 cm. in length, 5 cm. in breadth and 4 cm. in its anteroposterior diameters. It contains several interstitial myomas. In the left round ligament near the uterus is a spherical nodule 1.5 cm. in diameter (Fig. 30). This is partly covered by adhesions. The left tube reaches a diameter of 1 cm. Its fimbriated end is constricted but open. The ovary is normal in size. It contains a corpus luteum and is partly covered by adhesions.

Histologic Examination.—This shows that the nodule in the left round ligament is riddled with large islands of typical uterine mucosa (Figs. 31 and 32).

UTERINE MUCOSA IN THE OVARY

In 1898 my colleague, Dr. William Wood Russell, reported a case in which the ovary, although showing little increase in size, contained large islands of uterine mucosa. The report of this case was published

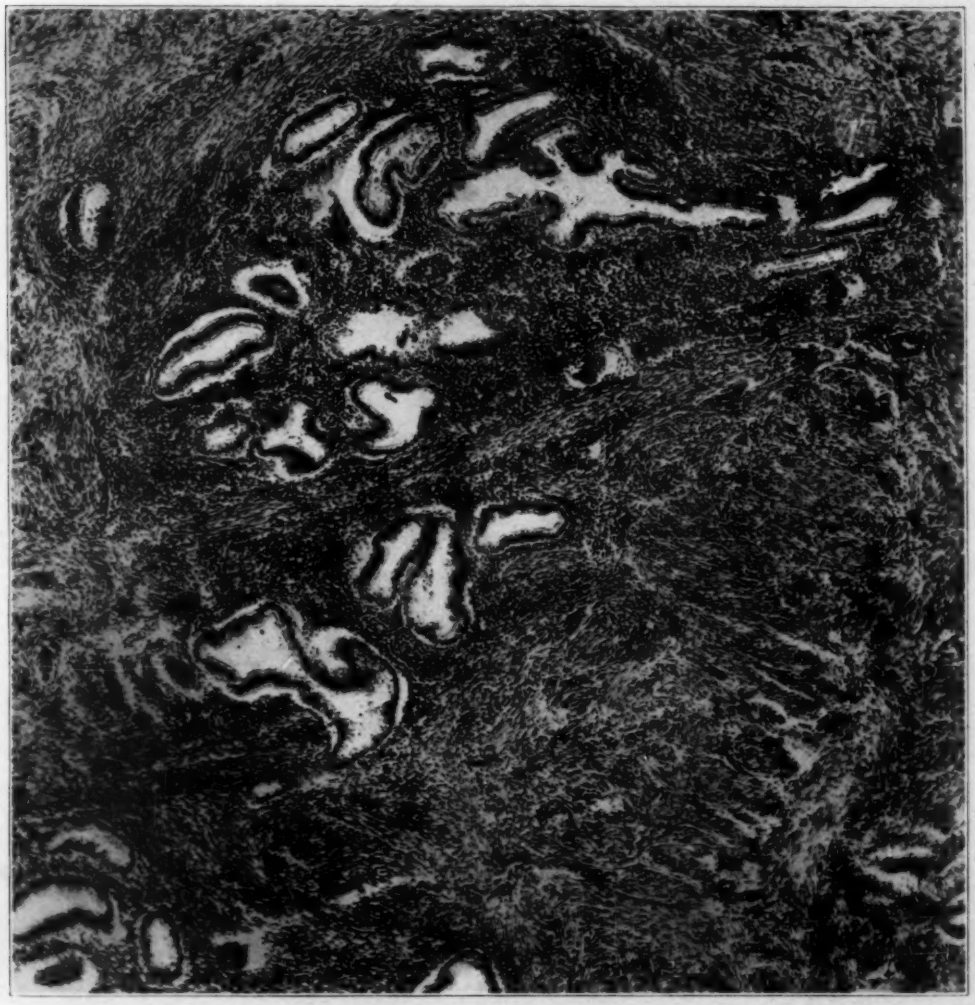


Fig. 32 (Case 12).—Adenomyoma of the round ligament. For the gross appearance, see Figure 30, and for the low power picture, Figure 31. The round ligament nodule consists of myomatous tissue. It contains large quantities of normal uterine mucosa.

in detail in the *Bulletin of Johns Hopkins Hospital* for that year, and the article is freely illustrated.

Within the last year Dr. Charles Norris of Philadelphia sent me a section of a relatively small ovary containing a large island of normal uterine mucosa (Figs. 33 and 34).

Dr. DeWitt B. Casler, of our department, at the 1919 meeting of the American Gynecological Society reported a unique case which has a definite bearing on this subject.

The patient, a trained nurse, 38 years of age, had had excessive periods for one year. On examination the uterus was found to be three times its usual size. Hysterectomy was performed. The increase in size was due to a diffuse myomatous thickening, and scattered throughout this diffuse growth were quantities of stroma identical with that of the uterine mucosa. This stroma, however, contained no glands. The tumor resembled in every particular the picture of an ordinary adenomyoma of the uterus save for the fact that the glands were missing from the stroma.

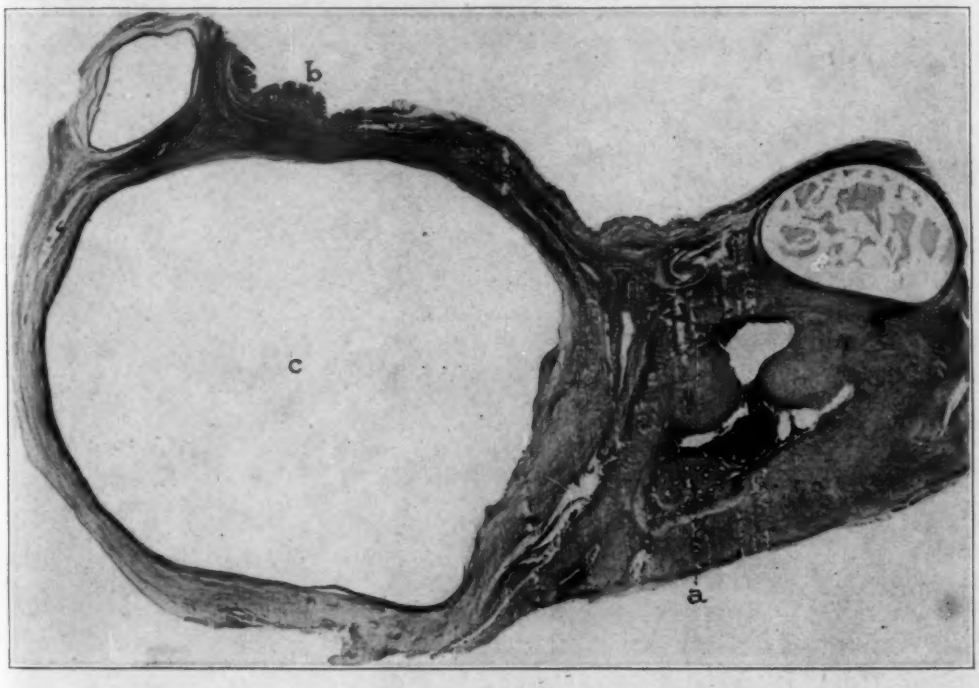


Fig. 33.—An ovary containing uterine mucosa. This is a very low power photomicrograph of a section through an entire ovary that was little enlarged. It was sent me by Dr. Charles Norris of Philadelphia. On the left is a relatively small cyst, *c*. At *a* in the substance of the ovary is a large area of typical uterine mucosa. This is connected with an irregular cyst cavity. On the upper edge of the section is normal tubal mucosa, *b*. The tubes have evidently been intimately adherent to the ovary. In Figure 34 one sees a higher magnification of the mucosa.

This patient after the complete hysterectomy still continued to menstruate regularly through the vaginal vault. A vaginal examination about three and one-half years after the hysterectomy revealed the fact that the ovary which had been left was perfectly normal in size. A little later it commenced to grow larger and when the abdomen was opened four years after the hysterectomy, this ovary was the size of a medium-sized grape fruit.

On histologic examination great quantities of typical uterine mucosa were found scattered throughout the ovarian tumor, thus clearly explaining why the

patient had continued to menstruate without any uterus. The ovary contained all the essential elements, normal ova, and practically normal uterine mucosa, and the small tract left where the uterus had been removed supplied the necessary avenue along which the menstrual flow escaped.

In the following case, in which the uterus was about three times enlarged as a result of interstitial and submucous myomas and in which the appendages were glued together by adhesions, the right ovary contained small areas of typical uterine mucosa.

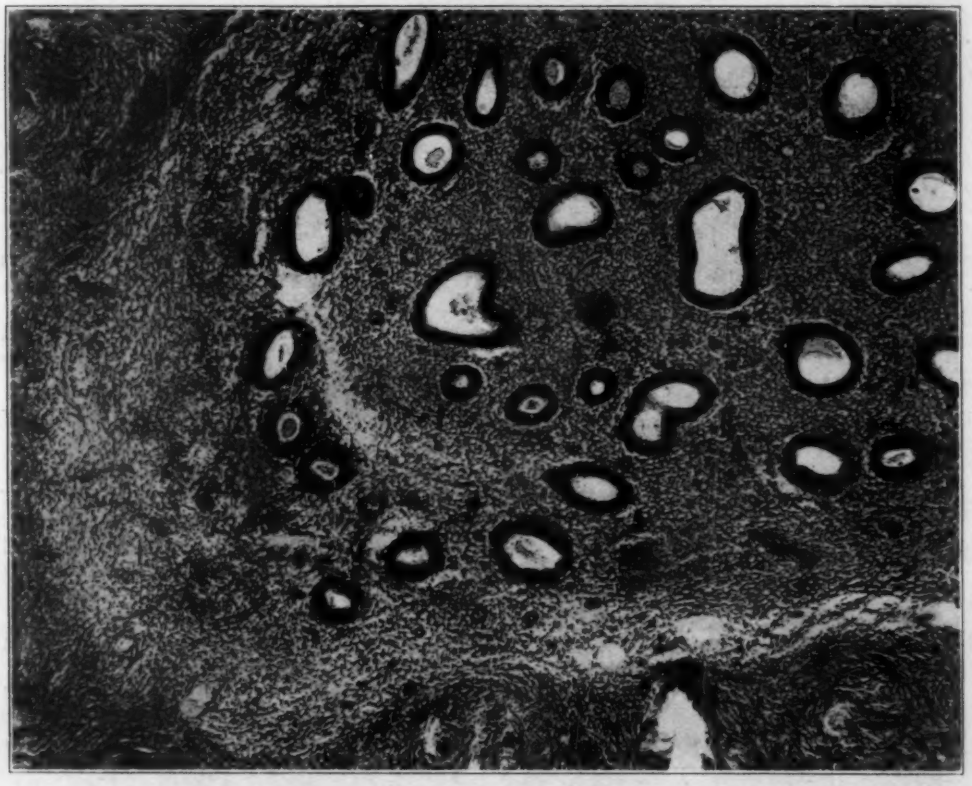


Fig. 34.—Uterine mucosa in the ovary. This specimen was sent me by Dr. Charles Norris of Philadelphia. For the low power picture, see Figure 33. The area of mucosa is sharply defined and consists of typical uterine mucosa embedded in the substance of the ovary.

CASE 13.—*A myomatous uterus with adherent appendages on the right side, and on the left a small ovarian cyst containing uterine mucosa in its walls* (Figs. 35 and 36).

Examination of Specimen (Gyn. Path. No. 22505, Sept. 19, 1916).—The specimen consists of the supravaginally amputated myomatous uterus together with the appendages (Fig. 35).

The portion of the uterus present is 10 cm. long, 10 cm. broad and 10 cm. in its anteroposterior diameter. At the fundus anteriorly are a few omental adhesions. Occupying the posterior wall of the uterus is a myoma 8 cm. in diameter. Scattered throughout the anterior wall are several nodules, the

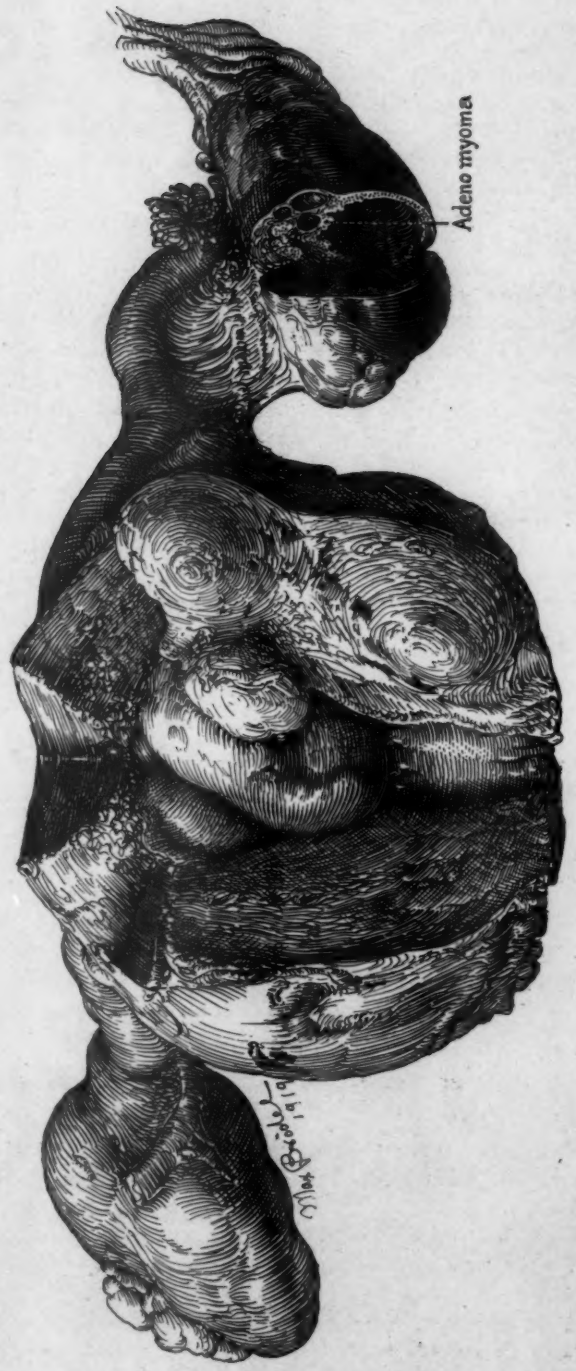


Fig. 35 (Case 13).—A myomatous uterus with adherent appendages on the right side and on the left a small ovarian cyst containing uterine mucosa in its walls. The uterus contains subperitoneal, interstitial and submucous myomas. The left ovary contains a cyst lined in part by uterine mucosa (Fig. 36).

largest 3 cm. in diameter. Projecting into and filling the cavity of the uterus is a myoma, 4 cm. long and 2.5 cm. broad.

Right Side: The tube is 8 cm. in length and varies from 8 to 10 mm. in diameter. Its fimbriated end is free. The ovary is 7 cm. in length. It reaches a thickness of 2.5 cm. Attached to the outer end is a moderate amount of fat. This appears to be omental in character. In the lower end of the ovary is what appears to be a collapsed corpus luteum cyst. It is about 4 cm. in length.

Left Side: The tube is 11 cm. long. At the cornu, it is 1.3 cm. in diameter. In its middle portion, it is a little smaller, but in its distal 5 cm. it varies from 2 to 2.5 cm. in diameter. Where dilated it has thin walls, a brownish inner surface and apparently contains old blood. Its fimbriated end is closed and between the closed end and the ovary, omental fat has become densely adherent. The ovary is 6 cm. long and varies from 2 to 3 cm. in thickness. It is covered by adhesions.

Histologic Examination.—It is difficult to get the exact relationship on account of the ragged condition of the specimen, but on microscopic examination of the left ovarian cyst, which was lined with a brownish membrane, it is seen that the cyst has an inner lining of cylindric epithelium which here and there tends to form folds. At some points beneath the epithelium there is a definite stroma and embedded in this are a few glands (Fig. 36). The cyst is partially filled with blood.

In a case (Gyn.-Path. No. 25003) in which the uterus was 13 by 11 cm., the enlargement was due to a submucous myoma. On the posterior surface of the cervix and lower part of the body of the uterus was the most widespread adenomyoma of the rectovaginal septum that I have even seen (Fig. 16). I had literally to cut the cervix away from the rectum.

On the surface of, and intimately attached to, the right ovary was a miniature uterine cavity (Fig. 21). The glands in this showed a moderate hypertrophy. Other sections from the same ovary showed a diffuse adenomyoma intimately blended with the ovarian tissue, so intimately that no line of demarcation could be detected. It must be remembered, however, that this ovary was firmly glued to and continuous with the diffuse adenomyoma that occupied the posterior surface of the uterus. It is quite possible that the uterine mucosa on the surface of this ovary was due to an overflow of the adenomyoma of the rectovaginal septum.

On Oct. 25, 1919, I received a very interesting letter from Dr. Otto Schwarz of St. Louis. In it he referred at length to several cases of adenomyoma that he had recently seen. Among other specimens examined was one in which the ovary contained uterine mucosa. Dr. Schwarz said:

> The ovarian case was most interesting; this ovary was removed about a year and a half ago. It was about the size of a hen's egg and showed nothing unusual externally. On section it showed several cavities which were filled with blood, partly clotted. Two large blocks were cut transversely across

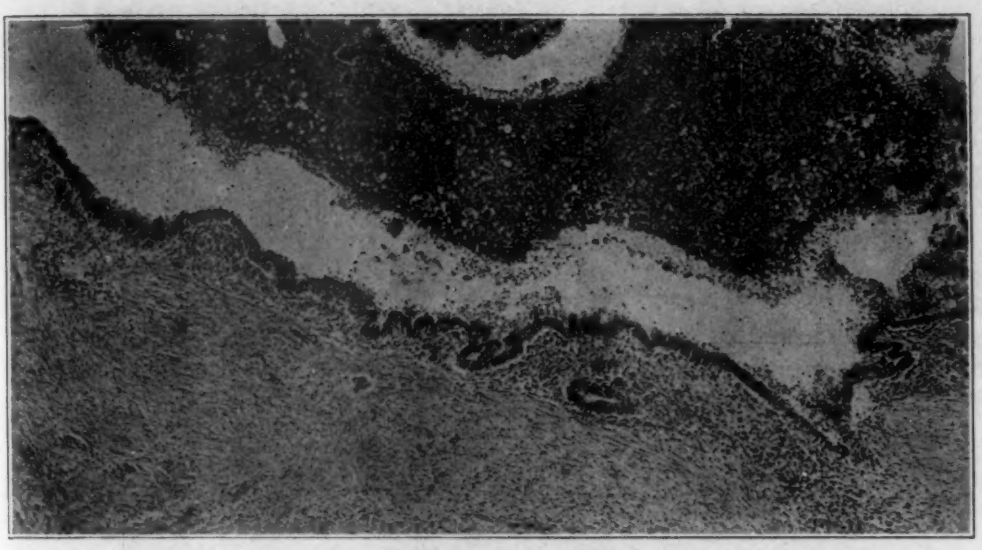


Fig. 36 (Case 13).—A small ovarian cyst lined in part by uterine mucosa. The débris in the upper part of the picture is composed chiefly of old blood. The cyst wall is lined by one layer of cylindric epithelium. In places, this lies in direct contact with the ovarian tissue, but here and there is separated by a definite stroma. Near the right, the stroma is very evident, and embedded in it is a gland resembling those of the body of the uterus. For the gross appearance, see Figure 35.

Fig. 37.—Uterine mucosa lining a small cyst in the ovary. The specimen was sent me by Dr. Otto Schwarz of St. Louis, Mo. The cyst wall is lined with cylindric epithelium. Beneath this in the central portion of the picture is a definite mucosa consisting of stroma and glands similar to those found in the body of the uterus.

the ovary. . . . In one of the sections I enclose the mucosa appears to communicate with the surface but this is due to a tear. Throughout the entire two blocks, the abnormal structure was well within the ovary. The sections show the lesion well demarcated from the rest of the stroma of the ovary. There are two cavities. These are lined with tissue similar to the endometrium.

I had the opportunity of examining other sections of the ovary with Dr. Schwarz in his laboratory at the Washington University in St. Louis a few months later. It is a beautiful example of an ovary containing miniature uterine cavities. Figure 37 is a photomicrograph that I have had made from one of Dr. Schwarz' sections.

Fig. 38 (Case 14).—Cyst of the right uterosacral ligament. During an operation for general pelvic adhesions, the cyst noted in the right uterosacral ligament was found. It was rather spherical, 1.5 cm. in diameter, and was filled with brownish putty-like material. It at once reminded me of an adenomyoma. Histologic examination, however, failed to reveal glands or any epithelial lining to the cyst.

From the foregoing it is evident that in due time a sufficient number of cases will undoubtedly be reported, and then we shall possibly be able to give a composite picture of both the clinical course and of the histologic changes that occur in this most unusual group of cases.

ADENOMYOMA OF THE UTERO-OVARIAN LIGAMENT

These are naturally of little clinical significance and will be recognized only in the laboratory. I have reported one case. A multinodular myomatous uterus was removed, and springing from the

utero-ovarian ligament was a myoma several centimeters in diameter. In the center of this were islands of typical uterine mucosa.

(This case was reported at length in my book on Adenomyoma of the Uterus, page 140, Figs. 41 and 42.)

ADENOMYOMA OF THE UTEROSACRAL LIGAMENT

Several years ago my colleague, Dr. William Wood Russell, removed a pea-sized nodule from the right uterosacral ligament. On histologic examination it presented a typical adenomyomatous picture.

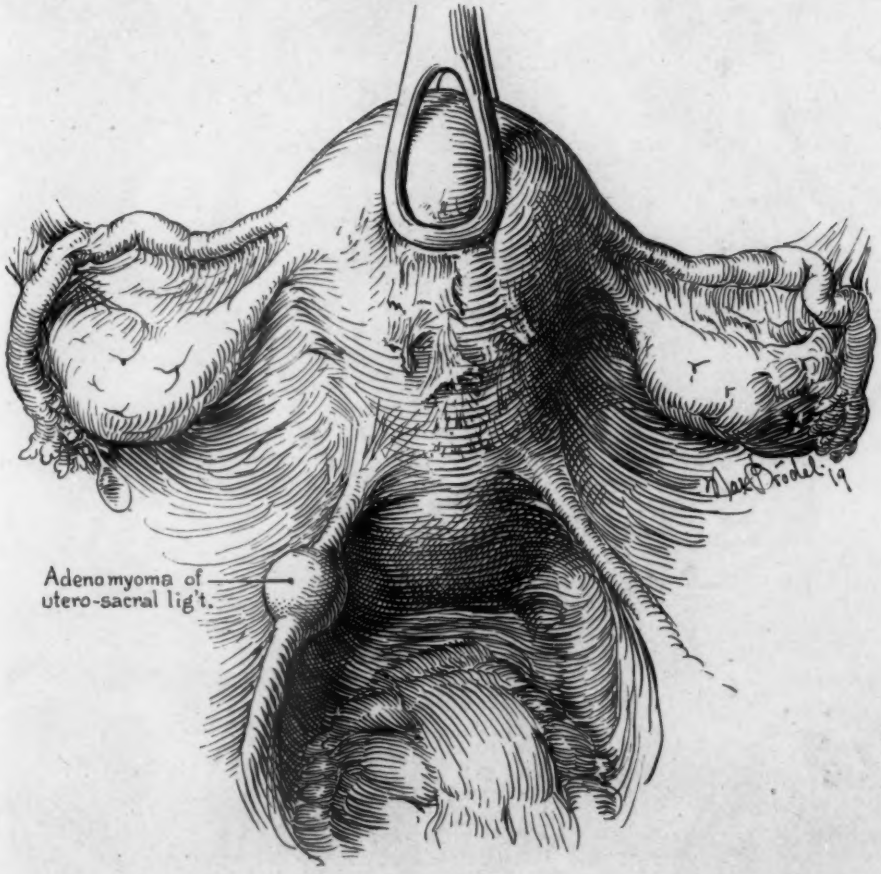


Fig. 39 (Case 15).—Adenomyoma of the left uterosacral ligament. On the posterior surface of the uterus are numerous adhesions. Both ovaries were lightly adherent. It was possible to save all the pelvic structures. In the left uterosacral ligament is a well circumscribed spherical nodule. This had a slightly yellowish brown tinge. For the histologic picture, see Figure 40. It was a typical adenomyoma.

Since then I have seen a cyst 1.5 cm. in diameter apparently springing from the right uterosacral ligament. It contained yellowish-brown putty-like material. It may belong to this group, but of this I cannot speak with certainty as the histologic picture was not very definite.

CASE 14.—*Possible adenomyoma of the right uterosacral ligament* (Fig. 38).

History (Gyn. No. 23906).—A B., aged 28, colored, was admitted to the Johns Hopkins Hospital on April 5, 1918. In the course of an operation for intestinal and omental adhesions and bilateral ovarian cyst, a small nodule was found in the right uterosacral ligament.

Fig. 40 (Case 15).—Adenomyoma of the left uterosacral ligament. For the gross appearance of the nodule, see Figure 39. Some of the glands lie in direct contact with the muscle, others are surrounded by the characteristic stroma.

Operation and Result.—The midline scar of a previous operation was excised. The omentum was found adherent along the line of the old scar. Scattered over the omentum and over the pelvic peritoneum were several small nodules varying from 2 to 3 mm. in diameter. These were made up of a brownish, putty-like material.

The body of the uterus was firmly attached to the abdominal wall to which it had evidently been sutured at a former operation. It was freed. There was a cyst about 5 cm. in diameter on the left side; this was resected. On the right side was a small cyst. This was also resected.

A tumor about 1.5 cm. in diameter was seen in the right uterosacral ligament, 3 cm. from the cervix (Fig. 38). This tumor felt rather firm and was covered with peritoneum. I dissected the right ureter free and pushed it outward. The peritoneum over the tumor was then opened, and the tumor

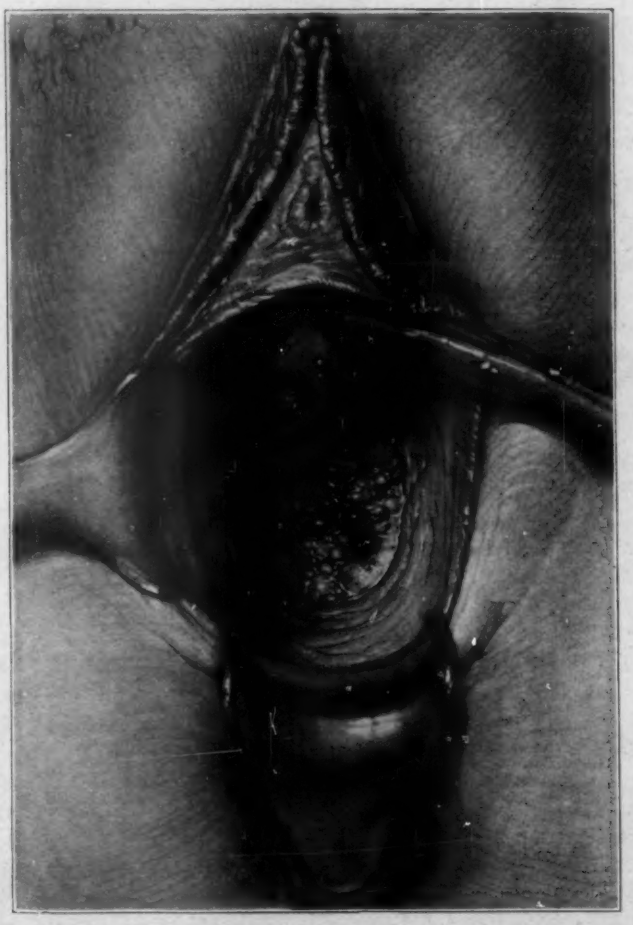


Fig. 41 (Case 16).—Adenomyoma of the rectovaginal septum. The neck of the uterus has been drawn strongly forward. Just posterior to the cervix is an oval and slightly raised area about 2.5 by 2 cm. The surface of this is roughened and lobulated. The surfaces of some of the lobulations are somewhat cystic and a few of them were bluish black, indicating that they contained old menstrual blood. This area was firmly fixed to the right side of the pelvis. For the abdominal picture, see Figure 42, and for the histologic picture, Figure 43.

found to be yellowish red. It was excised. During its removal there was an escape of a light yellow, oily, caseous material. The peritoneum was brought together and the abdomen closed. A small cigaret drain was laid in the lower angle of the abdominal incision. The patient was discharged April 29, 1919.

Examination of Specimen (Gyn. Path. No. 23986).—The specimen consists of a collapsed cyst, 1.5 cm. in diameter. This, as noted at operation, apparently sprang from the right uterosacral ligament. It contained yellowish brown, putty-like material which escaped during the operation.

Histologic Examination.—This revealed a wall consisting in large measure of fibrous tissue. There was no trace of epithelium.

Clinically, this case bore a striking resemblance to an adenomyoma, but whether it was actually an adenomyoma that had undergone retrograde changes, it is, of course, impossible to determine. We can think of nothing else that would occasion such a condition.

On May 20, 1919, I operated on a patient who had numerous pelvic adhesions. In the left uterosacral ligament a short distance from the uterus was a rounded nodule 1.5 cm. in diameter. I isolated the left ureter and then removed the nodule, bringing the several ends of the ligament together again. This nodule on histologic examination proved to be a typical adenomyoma. The case is as follows:

Case 15.—*Adenomyoma of the uterosacral ligament* (Figs. 39 and 40).

History.—Miss N. E. T., aged 36, white, was admitted to the Church Home and Infirmary (No. 21398) on May 19, 1919. I saw her in consultation with Dr. A. E. Plumb on April 24. Her menses began at 15. At first, they were regular, but for a year they had at times been a week ahead. On the second day they were accompanied by a good deal of pain. The last period had begun two weeks before I saw her.

Two years ago, she had an attack of acute appendicitis and for six months had had intense pain above the pubic bone. On examination, I found that she had a good deal of discomfort just above the symphysis and some tenderness in the appendix region. The outlet was slightly relaxed, the cervix was forward, the body of the uterus back on the bowel. No thickening could be made out on either side.

Operation and Result.—May 20, 1919, we dilated thoroughly. On opening the abdomen, we found the body of the uterus adherent to the rectum. Both tubes and ovaries were also adherent. The adhesions were loosened and the fimbriated ends of both tubes were found to be normal.

In the left uterosacral ligament was a thickening, 1.5 cm. in diameter (Fig. 39). This had a slightly yellowish brown tinge. It strongly suggested an adenomyoma, but I could not say with any degree of definiteness because the ovary was adherent over it. The ovary, however, did not contain any corpus luteum. After releasing the adhesions, we dissected out the left ureter so that we would know exactly where we were. We then cut away the growth from the left uterosacral ligament and in so doing cut across the uterine artery which was immediately grasped and tied. After cutting away the growth in the uterosacral ligament, we brought the ends of the ligament together with catgut, made a purse-string suture over the area and drew things together leaving the site of the nodule perfectly smooth. We then attached the fundus to the anterior abdominal wall with one plain and two chromicized catgut sutures just to hold the uterus up in position for a month or two and give it a chance to diminish in size. We feared there might be a low grade infection and consequently did not attempt to shorten the round

Fig. 42 (Case 16).—Adenomyoma of the rectovaginal septum, independent adenomyoma of the sigmoid almost completely blocking the lumen of the bowel. The right appendages have been removed, the right broad ligament opened up, the right uterine artery ligated and cut and the ureter dissected out. The vagina has been opened and the adenomyomatous thickening on the posterior vaginal wall cut away from the vagina and left attached to the rectum. We were preparing to push the adenomyomatous area together with the adjacent rectum down so that it would be entirely extraperitoneal and so that it could be removed through the vagina a few days later. At this moment, however, we noted the puckered area at the pelvic brim. This bore a strong resemblance to carcinoma, but no metastases could be found, so we came to the conclusion that it also might be an adenomyoma. The peritoneum of the sigmoid was then severed on either side to a point well above this second growth, the entire mass was pushed down to the pelvic floor and the peritoneum so drawn over it that the entire area was practically extraperitoneal. The abdomen was then drained. We expected to remove the entire diseased area from below at a later date. The patient, however, died of infection. At necropsy the sigmoid growth was found, as indicated by the picture, to have blocked almost completely the lumen of the bowel. It was a typical adenomyoma. This accounted for the fact that the bowel symptoms were so marked at the time of menstrual period. For the histologic picture of the adenomyoma of the sigmoid, see Figure 43.

ligaments. We removed the appendix which was small, but the meso-appendix showed scars of old trouble. The patient was discharged June 12, 1919.

September 22, the patient looked very much better. The uterus was in perfect position and there was no thickening anywhere in the pelvis.

Examination of Specimen (Gyn. Path. No. 25042).—It was noted at the time of operation that this nodule was 1.5 cm. in diameter. On section it is found to be composed of nonstriped muscle and fibrous tissue, and embedded in this are one or more minute discrete myomas. This nodule also contains a small amount of adipose tissue. The myomatous and fibrous tissue tends to spread out into the surrounding fat. Scattered throughout the diffuse myoma are numerous glands (Fig. 40) lined with one layer of cylindric epithelium. A few of the glands occur singly and lie in direct contact with the muscle. They tend, however, to occur in groups and are surrounded by the characteristic stroma. Some of the dilated glands contain fresh blood, others débris and exfoliated epithelial cells which have swollen, become spherical and contain yellowish brown pigment—the remnant of old menstrual blood.

This is a well defined example of adenomyoma of the uterosacral ligament.

ADENOMYOMA OF THE SIGMOID FLEXURE

In February, 1918, Dr. Thomas E. Neill of Washington, D. C., referred to me a patient, aged 26, complaining of most excruciating menstrual periods. Since April, 1917, she had had diarrhea and with the beginning of each period she would have definite intestinal spasms three or four times a day. These would last two days and they would occur just at the time the patient went to stool. In September, she was put on a milk and egg diet. Her digestion was very much upset and she became constipated. During the last three or four periods she had had pain in the lower bowel commencing about twenty-four hours before the period. She also had some bleeding from the bowel and had spasmodic contraction of the lower bowel causing nausea and retching.

On vaginal examination, I found a hard, slightly nodular and raised area in the vaginal vault directly behind the cervix. It was evident that this tumor contained several small cysts.

At operation we found, in addition to the adenomyoma of the rectovaginal septum, an independent growth in the sigmoid near the pelvic brim. This presented the typical appearance of carcinoma and I at once carried my hand up to the liver to see if there were any metastases. None being felt, I thought there might possibly be some relationship between the adenomyoma of the septum and that near the pelvic brim. As the patient's condition was not very good, we just loosened up the sigmoid and drew it down extraperitoneally hoping to remove it at a second operation a few days later. Unfortunately, the patient developed a streptococcus peritonitis and died. At necropsy, it was found that the sigmoid growth was a typical adenomyoma and that there was not the slightest trace of cancer.

This case is of such interest that I shall report it in detail.

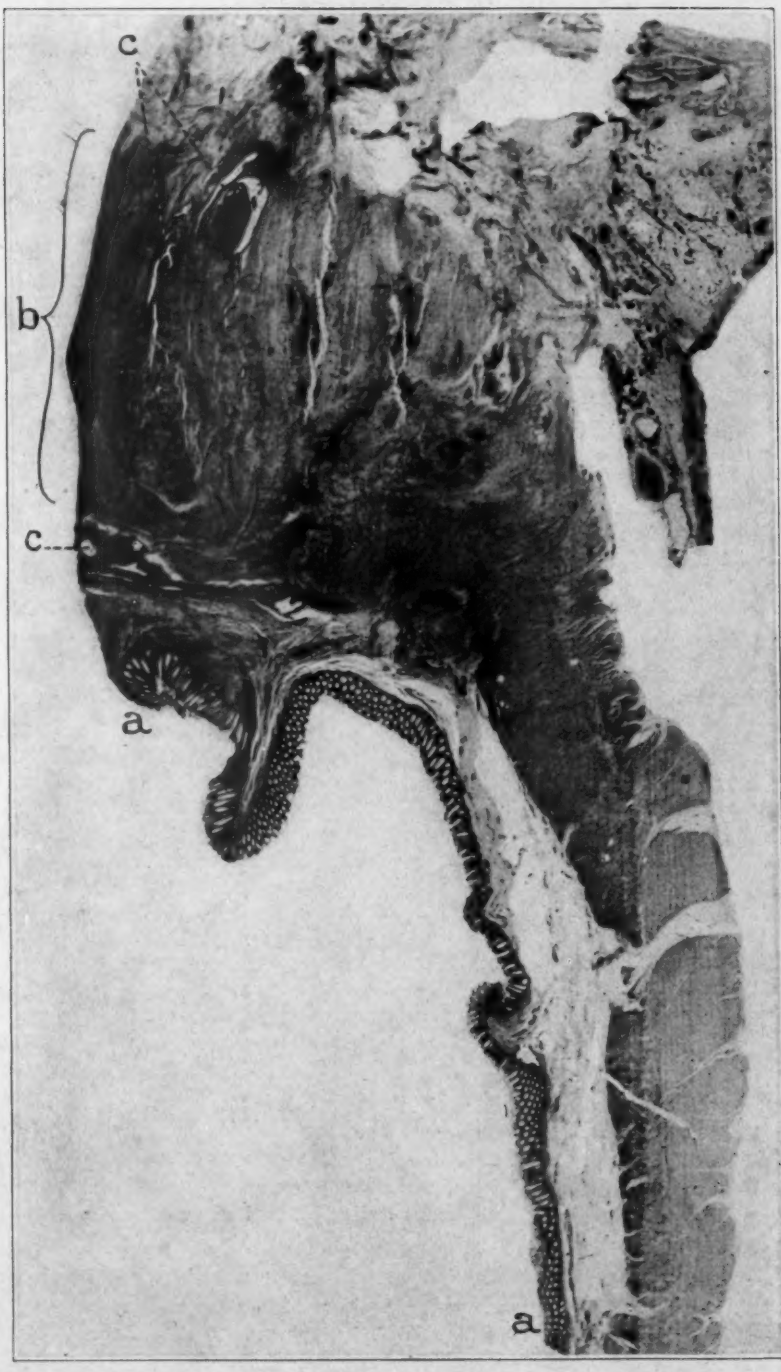


Fig. 43 (Case 16).—Adenomyoma of the sigmoid flexure totally independent of a coexisting adenomyoma of the rectovaginal septum. This is a photomicrograph of a section taken from the sigmoid growth seen in Figure 42. The rectal mucosa, *a*, is perfectly normal. At *b* the underlying muscular walls are greatly thickened. Scattered throughout the muscular tissue were uterine glands surrounded by the characteristic stroma. The tissue was unusually brittle, and it was impossible to obtain thin sections. Nevertheless, at *c* we can recognize glands and stroma in the muscle.

CASE 16 (Septum Case 19).—*Adenomyoma of the rectovaginal septum with an independent adenomyoma in the sigmoid flexure near the pelvic brim, clinically closely simulating a carcinoma of the sigmoid and markedly narrowing the lumen of the bowel* (Figs. 41, 42 and 43).

History (Gyn. No. 23764, Gyn. Path. No. 23891).—Mrs. G. S., aged 26, was referred to me by Dr. Thomas E. Neill of Washington on Feb. 11, 1918. Her menses began at 13. When 14, they occurred every three weeks. She was dilated and curetted when 16, and was gradually having more comfortable periods. The flow now lasted three and four days, formerly it lasted from ten days to two weeks. She had had severe headaches, but these had been

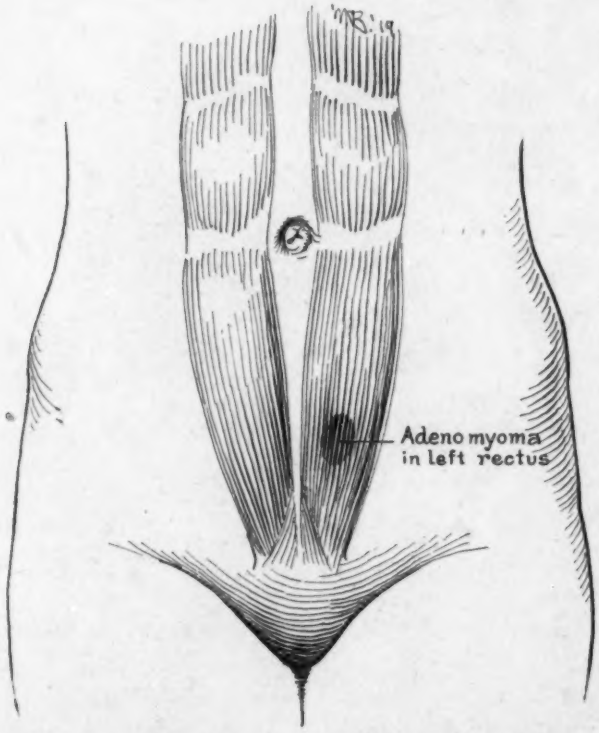


Fig. 44.—Adenomyoma in the left rectus muscle. Dr. Shallenberger's case. For the histologic picture, see Figures 45 and 46.

diminishing. She had also had the marked intestinal symptoms referred to above. Her last period was two weeks before I saw her. She gave no history of any previous serious illness.

Examination.—On pelvic examination, the outlet was found to be slightly relaxed, the cervix pointed forward. Just behind the cervix was a globular, somewhat lobulated mass, 2 cm. across, 2 cm. from above downward. It commenced directly behind the cervix. The body of the uterus itself was normal in size, in good position, and no thickening could be made out on either side.

On admission to the Johns Hopkins Hospital, the patient had hemoglobin of 78 per cent. She was in rather poor condition and I put her on forced

nourishment for two weeks before attempting any abdominal procedure. Dr. M. Bloomfield examined the lungs and found evidence of old tuberculosis in the left apex.

Operation and Result.—April 4, 1918, we operated. First of all we grasped the posterior lip of the cervix and drew it forward, put a retractor in posteriorly and then one on the right. We were then enabled to see an oval area, about 2.5 by 2 cm., directly behind the cervix (Fig. 41). This was slightly nodular and in the center of some of the nodules was a shiny condition indicating that at such points a small cyst existed. One or two of these were bluish black in color, and there was absolutely no doubt that we were deal-

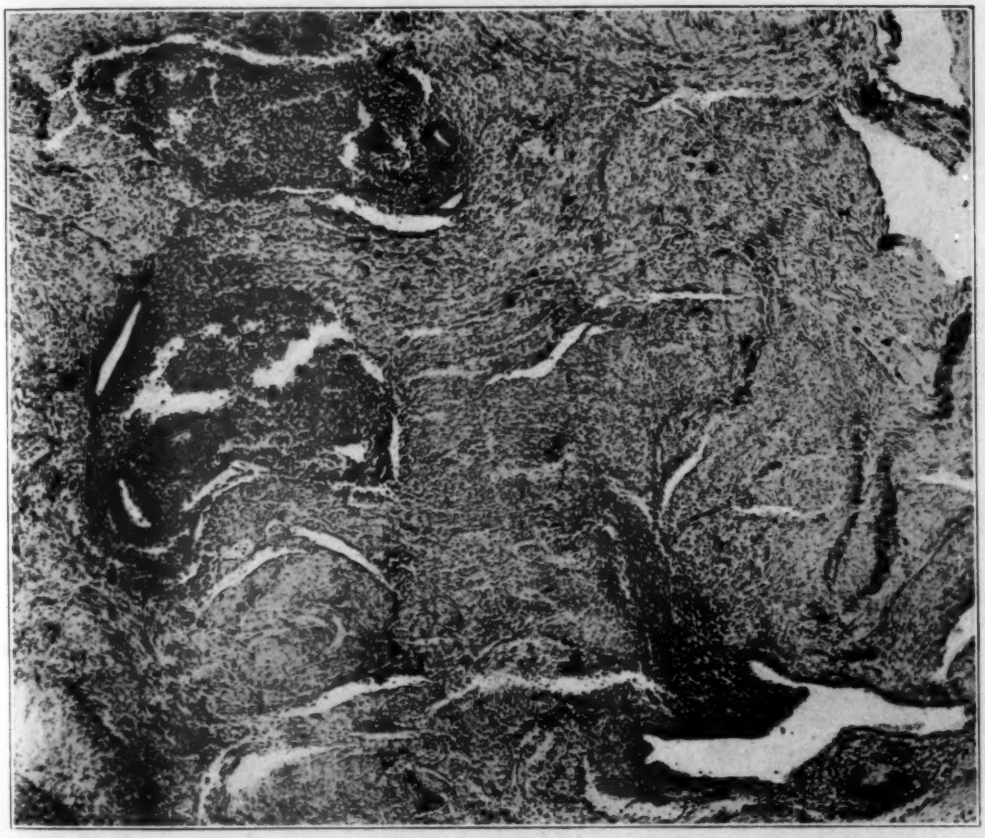


Fig. 45.—Adenomyoma in the left rectus muscle. For the location of the tumor, see Figure 44. The nodule consisted of nonstriped muscle and fibrous tissue, and scattered throughout it were areas of typical uterine mucosa.

ing with an adenomyoma of the rectovaginal septum. The edge of the growth was slightly raised, probably 1 mm. from the surface of the vaginal mucosa. We made an incision posterior to the cervix, separated the cervix from the vagina and then on the right side we cut the vaginal mucosa near the growth and loosened it up as much as possible. We then packed the vagina tightly with gauze and made a median abdominal incision. The right tube and ovary were removed in order that we might get into the right broad ligament satisfactorily. We dissected out the right ureter, cut the right uterine artery and

then separated the bladder peritoneum from the anterior surface of the uterus to a point slightly beyond the median line. We gradually loosened up the growth in the right broad ligament from the peritoneum on the right side of the rectum for a short distance and then cut the vaginal mucosa around it so that we finally had the uterus shoved over to the left side and a button of the vaginal mucosa containing the growth still left attached to the rectum (Fig. 42). We had partly closed the vagina, after pulling the rectal growth down into it, when we noticed a constriction about six inches above where the rectal growth had been. Whether the growth in the upper part of the sigmoid was carcinoma or not it was impossible to tell. After examining the pelvic glands and also the liver and finding no evidence of metastases nor any enlarged lymph glands, I came to the conclusion that this might be another adenomyoma, although I had never seen one in such a position. We cut the peritoneum on either side of the sigmoid up as high as the pelvic brim,

Fig. 46.—Adenomyoma in the left rectus muscle. For the location of the tumor, see Figure 44. Scattered throughout the myoma are areas of normal uterine mucosa.

loosened up the rectum as far as possible without interfering with its blood supply and then pushed the sigmoid well down into the pelvis and drew the pelvic peritoneum over to the pelvic brim so we could wall off this area of the sigmoid. When we had finished the operation, the sigmoid had been pushed down extraperitoneally. A drain was left in the lower angle of the incision down behind the uterus. The patient was in fair condition.

We hoped at a later date to draw the bowel out through the vagina and perform an end to end anastomosis if possible. To have done anything more at the time would undoubtedly have caused the death of the patient.

For the first twenty-four hours the patient did fairly well, but the next day she commenced to vomit a small amount of greenish fluid. There was a good deal of abdominal distention.

On March 7, the patient was delirious, vomited frequently, and was very restless, tossing from side to side. On March 8, at 3:30 p. m., I performed an enterostomy, thinking there might be intestinal obstruction. The bowel was relatively smooth, but there was some infection low down in the pelvis. The patient died at 9 p. m.

Necropsy Findings.—A definite peritonitis existed. The rectovaginal growth consisted of typical adenomyomatous tissue, and the tumor that projected in the sigmoid near the pelvic brim and markedly constricted the lumen of the bowel also consisted of characteristic adenomyomatous tissue (Fig. 43).

Cuthbert Lockyer,[5] in his excellent book on "Fibroids and Allied Tumors," gives us the best résumé of the literature on adenomyoma. In it, he refers at length to an interesting case reported by Robert Meyer.[6] On referring to Meyer's article I found that the patient was 45 years of age, and that Professor Mackenrodt had performed a resection in 1907 as the patient had signs of stenosis of the bowel.

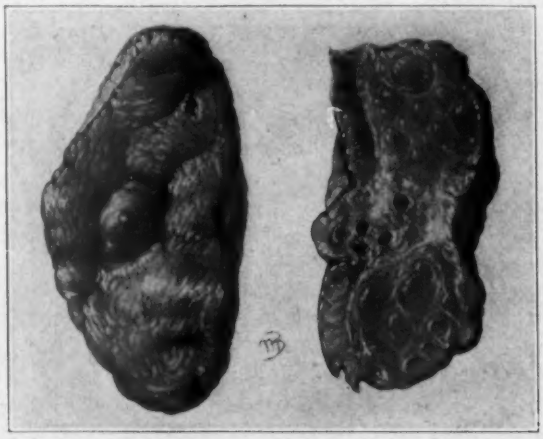


Fig. 47 (Case 17).—Adenomyoma of the umbilicus. Dr. Guthrie's case. Projecting from the umbilical depression is a small tumor. This was 1.5 cm. long. On section it was seen to contain several small cysts. Some of them were yellowish brown color. For the low power picture, see Figure 48. For the higher magnification, Figure 49.

The specimen consisted of a segment of the bowel 8 cm. in length. The bowel lumen over an area 1.5 cm. long was markedly narrowed, there being just a slitlike opening. The mesocolon at this point and also the overlying bowel mucosa were markedly thickened. In the mesocolon between the layer of fat and the muscular wall of the

5. Lockyer, Cuthbert: Fibroids and Allied Tumors, New York, the Macmillan Company, 1917.

6. Meyer, Robert: Ueber entzündliche heterotope Epithelwucherungen im weiblichen Genitalgebiete und über eine bis in die Wurzel des Mesocolon ausgedehnte benigne Wucherung des Darmepithels, Virchows Arch. f. path Anat. **195**:487, 1919.

sigmoid was an irregular fanlike connective-tissue tumor, diffuse in character, and strongly suggesting an adenomyoma. The tumor projected into the bowel and produced a folding of the overlying mucous membrane.

On histologic examination, the mucous membrane of the bowel over the tumor folds was found to have practically disappeared, the surface consisting of granulation tissue. The tumor consisted of adenomyomatous tissue.

Meyer's pictures leave no doubt that he was dealing with an adenomyoma of the sigmoid, an adenomyoma of a type resembling in nearly every particular that found in the uterus. This is the first case of this character that I have found any record of. It was clearly described in Cuthbert Lockyer's recent publication.

On Oct. 24, 1919, I received a most interesting letter from my friend, Dr. G. Brown Miller of Washington, D. C., the contents of which have a definite bearing on the association of adenomyoma of the rectovaginal septum with secondary adenomyoma in the sigmoid.

Mrs. P., aged 36, with no children, came to see Dr. Miller on June 26, 1919, complaining of profuse, prolonged and painful menstruation, pain in the pelvis and pain on defecation. She had recently lost a good deal of weight but was still well nourished although somewhat anemic.

Vaginal examination showed the cervix to be large and hard, and a small polypoid tumor was protruding from the os. In the upper part of the posterior vaginal vault was an irregular, hard, nodular tumor mass the size of a walnut. It was intimately connected with the cervix, rectum and broad ligament. The rectal mucosa over the tumor was intact but was intimately adherent to the mass. The uterus was retroverted and moderately enlarged. A diagnosis of adenomyoma of the rectovaginal septum was made.

The patient was sent to the Columbia Hospital and was operated on a few days later. I was assisted by Dr. Neill. When more carefully examined immediately before operation the nodules in the vaginal vault were seen to contain small bluish cysts the size of a pin.

On opening the abdomen the first thing which attracted one's attention was a mass the size of a large lemon which was situated in the upper part of the rectum or lower sigmoid. This seemed to encircle the lumen of the bowel. The patient gave no history of hemorrhage from the bowel or of bloody stools. A total hysterectomy was performed. It was a difficult operation on account of the fixation of the uterus. In attempting to separate the growth from the rectum, an opening was made in the bowel after which the whole involvement of the rectum by the tumor was cut away and the rectum was sutured.

No attempt was made to resect the growth in the sigmoid. The patient left the table in bad condition. Her pulse was rapid and she was much shocked. She improved and the next day was much better. I left town the following day and was hopeful that she might recover, but learned from Dr. Neill that about eight or nine days after the operation she apparently developed peritonitis and soon died.

Mahle and MacCarty[7] report a very interesting case of adenomyoma of the sigmoid observed in the Mayo Clinic:

CASE 4.—The adenomyoma of the sigmoid occurred in a patient, aged 31, who had been married eleven years and pregnant once. She had had an appendectomy, salpingectomy, and partial oophorectomy performed elsewhere. At that time she was told that she had a tumor of the lower bowel which would

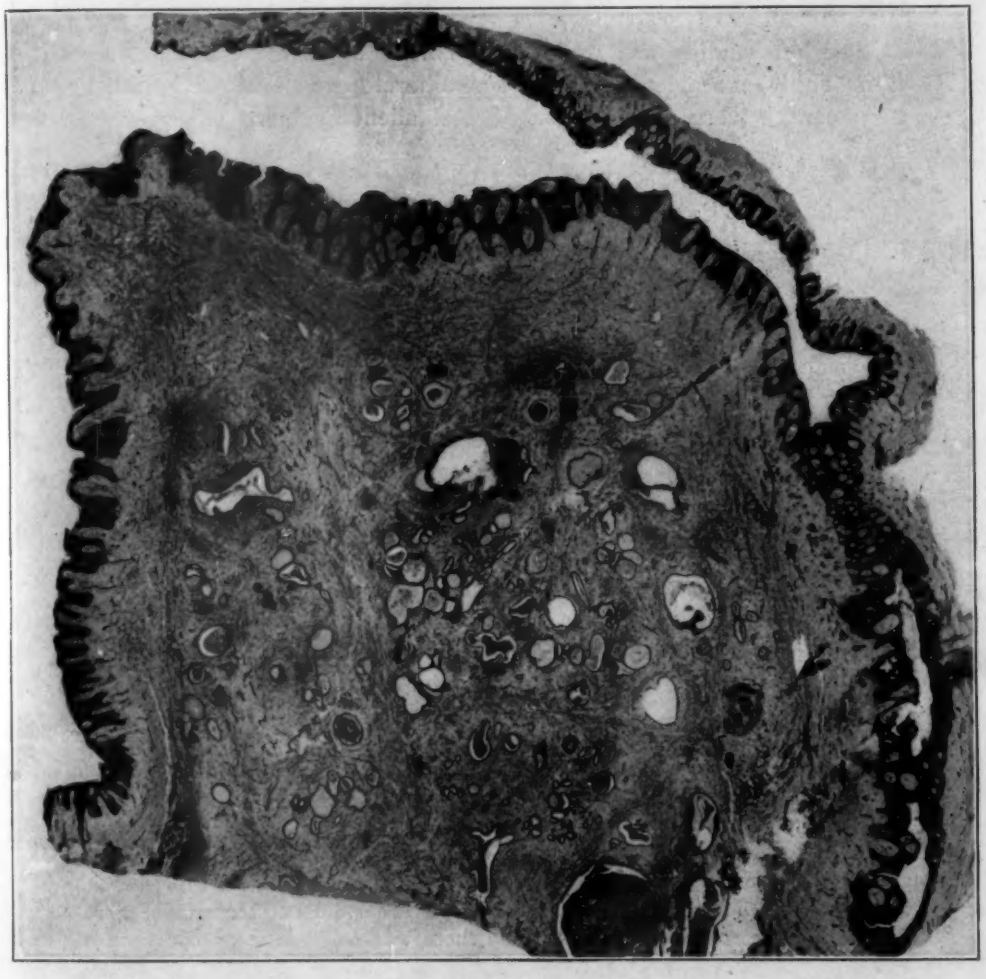


Fig. 48 (Case 17).—Adenomyoma of the umbilicus. This is a low power picture of the umbilical tumor seen in Figure 47. The surface is covered with normal skin. Scattered everywhere throughout the tumor are glands, many of them cystic, and not a few surrounded by a definite stroma that stains rather deeply. For the higher power, see Figure 49.

become a cancer. She presented herself at the clinic because of this tumor. Roentgen ray of the colon, and a proctosigmoidoscopic examination proved negative.

7. Mahle, A. E., and MacCarty, W. C.: Ectopic Adenomyoma of Uterine Type (A Report of Ten Cases), J. Lab. & Clin. M. **5**:221 (Jan.) 1920.

At operation a tumor mass was found encircling the sigmoid, involving a segment of the bowel 4 cm. in length. The sigmoid and the bladder were adherent to a mass around the uterus. Twelve centimeters of sigmoid were removed as well as "tarry" cysts of both ovaries.

Histologic examination of the sigmoid growth showed the characteristic picture of adenomyoma. Mahle and MacCarty refer to an adenomyoma of the sigmoid observed by Leitch.

Further studies will undoubtedly bring to light other cases and it is highly probable that some cases heretofore considered to have been cancer were as a matter of fact adenomyomas.

ADENOMYOMA OF THE RECTUS MUSCLE

These growths are exceedingly rare. Dr. William F. Shallenberger of Atlanta kindly sent me a résumé of the history of his case on Nov. 8, 1919.

History.—Mrs. C. E. D., aged 34, had been married more than ten years. Nine and a half years ago she had an abortion. Curettage was performed for retained membranes and the dilator passed through the retroflexed uterus at the cervical uterine junction. The body of the uterus was torn half loose from the cervix before the accident was discovered. The patient evidenced considerable shock, was rushed to the hospital, the abdomen was opened and the damage repaired.

Dr. Shallenberger also learned that the patient had a second pregnancy eight years ago. She went to term, had a normal labor but following labor a hematoma developed in the left broad ligament and vaginal wall. This had to be opened through the vagina. The patient's health has been very good since the last labor, aside from a slight attack of cystitis three years ago and a streptococcus infection of the foot six months ago.

The menstrual history was normal in every way.

Present Illness.—Three days ago the patient noticed a little soreness in the lower abdomen just to the left of the lower angle of the abdominal scar (Fig. 44). On feeling this area she noticed a small tender swelling. She thought that a hernia was developing.

On inspection there was a slight fulness just to the left of the midline and slightly above the symphysis. On palpitation a small firm nodule could be felt apparently in the belly of the rectus muscle. This did not seem to be associated with the scar of the incision and there was no impulse on coughing or straining, and the nodule did not increase in size when the patient stood. Dr. Shallenberger thought he was dealing with a hernia or with a dermoid tumor of the rectus muscle.

Treatment.—The patient was put to bed and an ice cap was placed over the lower abdomen. The pain and soreness were not relieved and the nodule apparently increased somewhat in size during the next four days. Dr. Shallenberger then decided to remove the nodule. The entire lower end of the left rectus was removed. The tumor was about 2.5 to 3 cm. in length, about 1.5 cm. in breadth and 1.5 cm. thick. It had no definite capsule.

On cutting into the tumor Dr. Shallenberger found that it presented a dark grayish mottled appearance and that it was firm and fibrous in character.

The operation was performed eleven months ago and the patient made an uneventful recovery.

Sections from this growth sent to me by Dr. Shallenberger consist of nonstriped muscle. Scattered throughout this are areas of characteristic uterine stroma containing normal appearing uterine glands (Figs. 45 and 46). The cavities of some of the glands contain blood and in the stroma at some points is brown pigment.

The tumor in the case reported by Dr. Shallenberger is without doubt an adenomyoma occurring in the left rectus muscle. It is the first one of this character that I have ever heard of. From its location it could not for a moment be confused with adenomyoma of the round ligament which, although it presents exactly the same histologic picture, is usually situated at or near the external or the internal ring.

Mahle and MacCarty[7] record two cases of adenomyoma of the abdominal wall:

Case 2.—This patient, aged 30, complained of a tender lump, of two years' duration, in the lower abdominal wall, under a previous laparotomy scar. The lump was painful at the time of menstruation.

On examination a palpable mass, 3 cm. in diameter, was found beneath the lower end of a median laparotomy scar; this was hard, nodular and painful to touch. It was apparently not attached to the uterus, and clinically, was thought to be a fibrous tumor in a previous laparotomy wound.

At operation, the mass was removed; it extended through the abdominal muscles, and was attached to the left tube about 4 cm. from the uterine horn.

Case 3.—This patient, aged 46, had had a ventral suspension performed several years before and had been pregnant nine times, the last pregnancy occurring ten years before. She complained of lumps in the abdominal wall, which she had noticed for the last year. These lumps had not grown noticeably larger but had always been painful following menstruation.

On examination, a mass was found in the suprapubic region, apparently in the abdominal wall, movable with it, and possibly connected with the fundus of the uterus. Clinically, it was thought to be a fibrous growth, attached to the abdominal wall on a previously ventrosuspended uterus.

At operation, the fundus of the uterus was found attached to the abdominal wall. The tumor, 8 cm. in diameter, was situated to the right of the midline, and extended down to the right side of the uterus. It was solid, with glandular, cystic areas filled with black pigment. Because of its extension into the retroperitoneal tissue, and apparent inoperability, only a piece of tissue 6 cm. in diameter, was excised for diagnosis.

ADENOMYOMA OF THE UMBILICUS

From time to time a small thickening has been noted at the umbilicus in women during the child-bearing period. In some of these cases, the tumor has increased in size perceptibly at the menstrual

period, and in a few there has been a discharge of blood from the umbilicus at the period. Occasionally, small bluish black cysts have been noted in the tumor.

Adenomyomas of the umbilicus are always small. On histologic examination, they are found covered over with normal skin. They consist of fibrous tissue and nonstriped muscle, and scattered through-

Fig. 49 (Case 17).—Adenomyoma of the umbilicus. This section is from the umbilical nodule seen in Figure 47. In the center of the field is typical uterine mucosa. Some of the glands are dilated.

out this are islands of typical uterine mucosa. When the history is characteristic, the diagnosis can be made with ease.

It is not necessary for me to discuss this subject in detail, as I have devoted an entire chapter to adenomyomas of this region in my book on the umbilicus.

Removal of the umbilicus is all that is essential in these cases.

I shall report briefly on the specimens of two cases of adenomyoma that have recently been sent me for examination.

CASE 17.—*Adenomyoma of the umbilicus* (Figs. 47, 48 and 49).

History.—The specimen was sent me by Dr. Donald Guthrie of the Robert Packer Hospital, Sayre, Pa., in March, 1919. Dr. Guthrie says:

"The patient is 46 years of age. She has had two children—the youngest 16 years of age. Menstruation has been regular. The patient has experienced severe pain around the umbilicus at the menstrual period. She has noticed this for two years, and at this time discovered an enlargement of the umbilicus. She never has had any discharge from it. At the menstrual period when the

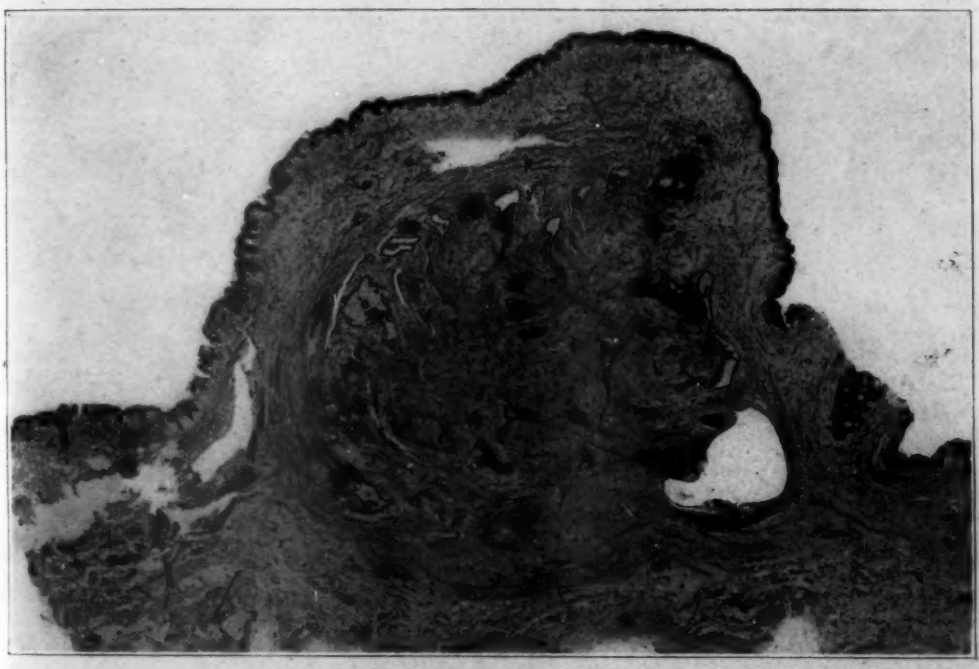


Fig. 50 (Case 18).—Adenomyoma of the umbilicus. The specimen was sent me by Dr. Lester Adams. The overlying skin is normal. The tumor is sharply circumscribed, has a whorled appearance, and has scattered throughout it cystic spaces and dark areas, some of them with glands in their centers. For the histologic picture, see Figure 51.

umbilicus was paining her, the patient experienced some inflammatory symptoms of the bladder. She has become very nervous and fearful that she has a cancer."

Dr. Guthrie sent me the specimen shortly after its removal.

Examination of Specimen (Gyn. Path. No. 24792).—The specimen consists of the umbilicus and of the adjoining skin. The umbilical depression is filled with a small growth 1.5 cm. in diameter (Fig. 47). This on section appears firm, but scattered throughout it are a few cystic spaces, some of them yellowish brown—cancer was suspected clinically.

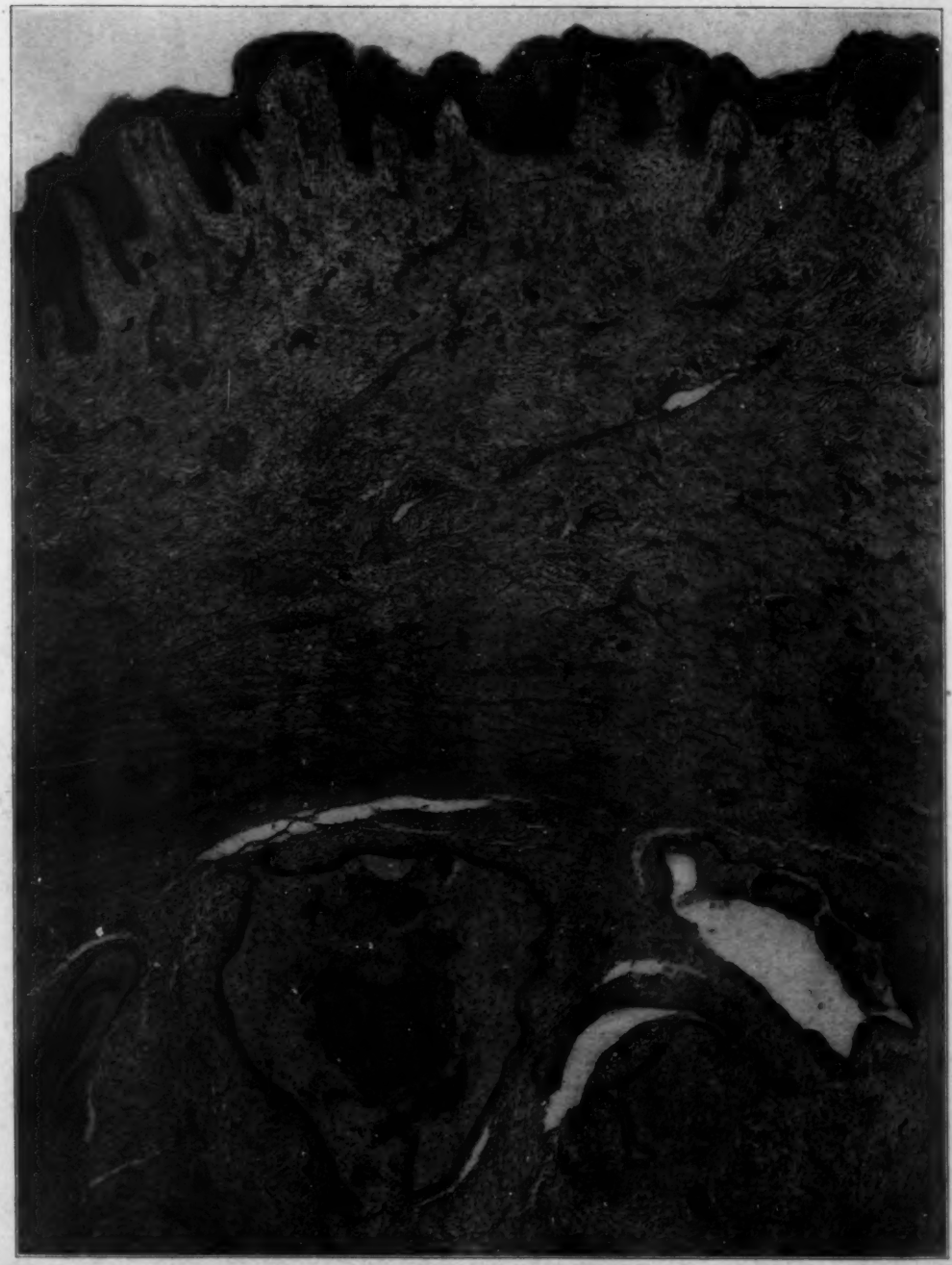


Fig. 51 (Case 18).—Adenomyoma of the umbilicus. The overlying skin is normal. Some of the glands are partially surrounded by a definite stroma, others lie in contact with the myomatous tissue. For the low power picture, see Figure 50.

Histologic Examination.—The low-power picture is well shown in Figure 48. The free surface is covered with normal squamous epithelium. The greater part of the tumor is made up of colonies of glands embedded in a definite stroma. Quite a number of the glands are dilated and filled with grayish or brownish material. Here and there is a perfectly definite miniature uterine cavity.

With a higher power it is seen that the matrix of the tumor is made up of connective tissue with bundles of nonstriped muscle scattered liberally throughout it. Everywhere throughout the tumor are glands. Some are minute and lie in direct contact with the muscle; others are larger and embedded in a rarefied stroma. Many occur in groups and are embedded in a stroma identical with that of the uterine mucosa (Fig. 49). This mucosa is in some places so arranged that miniature uterine cavities occur. Some of the gland cavities are filled with blood, and here and there throughout the stroma of the growth are areas of yellowish brown pigment—the remnants of old menstrual blood. One could not wish for a more beautiful example of an adenomyoma of the umbilicus.

CASE 18.—*Adenomyoma of the umbilicus* (Figs. 50 and 51).

History.—This specimen was sent me by Dr. Lester Adams of the Eastern Maine General Hospital, Bangor, Me. M. G., aged 37, was under the care of Dr. Hunt. An umbilical growth was removed on Nov. 8, 1916. About a year before the operation she had noticed pain at the umbilicus at the menstrual period, but at no other time. There was some increase in size of the umbilicus at the periods. Recently the pain and tenderness in the umbilical region had increased markedly.

Examination of Specimen (Gyn. Path. No. 22657).—The specimen consists of a growth, 1.3 cm. in diameter, occupying the umbilical region. On section it is very dense, but at two points are small cysts, the larger being 2 mm. in diameter.

On histologic examination, the overlying skin is found to be normal (Fig. 50). The tumor growth is made up of nonstriped muscle and fibrous tissue. Scattered throughout the tumor are large numbers of glands, some occur singly and lie in direct contact with the muscle. The majority, however, occur in groups and are separated from the muscle by a definite stroma (Fig. 51). This at some points is rarefied, but in other places is identical with that of the uterine mucosa. In at least one place is a miniature uterine cavity. Some of the glands are filled with blood, others with exfoliated epithelium and débris. In the outlying portions of the tumor are colonies of sweat glands.

This is another example of adenomyoma of the umbilicus.

SUMMARY

From the foregoing, we have seen that adenomyomas, consisting of a matrix of nonstriped muscle and fibrous tissue with typical uterine mucosa scattered throughout, are to be found in the uterus, rectovaginal septum, tubes, round ligaments, utero-ovarian ligaments, uterosacral ligaments, sigmoid flexure, rectus muscle and umbilicus, and that we occasionally find large quantities of normal uterine mucosa in the ovary. Adenomyomas form one of the most interesting groups of tumors that we have to deal with in the female pelvis.

STUDIES IN BONE TRANSPLANTATIONS

AN EXPERIMENTAL STUDY OF THE COMPARATIVE SUCCESS OF AUTOGENOUS AND HOMOGENOUS TRANPLANTS OF BONE IN DOGS *

BARNEY BROOKS, M.D., AND WILLIAM A. HUDSON
ST. LOUIS

The extensive clinical and experimental study of the results of transplantation in the same individual of free pieces of bone has led to a clear understanding of the successive steps in the ultimate success or failure of such transplants. The experiments of Phemister,[1] Haas,[2] Axhausen,[3] Thalhimer,[4] Brooks[5] and others leave no doubt that the free bone transplant is a source of regeneration of bone and does not act merely as trellis into which bone grows from neighboring sources. These investigators have further shown that the regenerating elements of the bone transplant are the inner layer of the periosteum and the endosteum lining the marrow cavity and the Haversian canals, and that the bone cells in the lacunae take no part in the regeneration of bone. This knowledge places the free autogenous bone transplant on a firm basis as a means of clinical repair of bone defects.

Furthermore, the number of instances in which autogenous free bone transplants have been used in experimental animals gives a fairly definite idea of the proportions of success and failure of such transplants when used to repair defects in the shaft of bone.

In the experimental transplantation of bone in dogs, with the periosteum and marrow surfaces preserved, we have found, barring obvious explanations of failure of the transplant, such as wound infection or poor position of the graft, that such transplants have been successful in all instances in which comparatively young animals have been used. In a series of experiments, reported in a previous paper,[6] in which old dogs alone were used, it was found that the proportion of successful regenerations of the bone defect by an autogenous bone transplant was reduced to approximately 66 per cent.

The knowledge concerning the transplantation of bone from one individual to another of the same species is very limited. The rather general failure of transplantations of tissue between individuals of

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* From the Department of Surgery, Washington University Medical School.

1. Phemister: Surg., Gynec. & Obst. **19**:303, 1914.
2. Haas: Surg., Gynec. & Obst. **19**:604, 1914.
3. Axhausen: Arch. f. klin. Chir. **88**:23, 1909.
4. Thalhimer, W. M.: Ann. Surg. **67**:331 (March) 1918.
5. Brooks, Barney: Ann. Surg. **65**:704 (June) 1917.
6. Brooks, Barney: Ann Surg. **69**:113 (Feb.) 1919.

PLATE I

a

b

c

d

Transplants: *a*, homogenous, Experiment 7 A; *b*, homogenous, Experiment 7 B; *c*, homogenous, Experiment 8 A; *d*, homogenous, Experiment 18 A.

even the same species has led to a fairly general impression that such transplantations are usually ultimately unsuccessful. In experiments in which homogenous transplants of bone have been used, however, successful results have been recorded, although there is no definite knowledge of the proportions of success and failure of homogenous bone transplants.

Ollier [7] apparently believed that transplantations of periosteum or bone and periosteum were equally successful when used in the individual or in another individual of the same species. He writes that although transplantations of periosteum from an individual of one species to an individual of another species is universally ultimately a failure, no difficulty was encountered in finding regeneration of bone from a transplant of periosteum from a rabbit to another rabbit of a different variety. Ollier's experiments, however, were all done previous to the time of antiseptic surgery, and there were numerous failures, due to wound infection, even in instances in which autogenous transplants were used. Also, Ollier was primarily interested in the proof of the osteogenetic properties of the periosteum, and one gets comparatively little information, other than that bearing directly on this question, from the study of his experiments. It is also of considerable interest to note that Ollier showed that bone was produced from a transplant of periosteum taken from a rabbit which had been dead twenty-five hours and transferred to a living rabbit. He also did experiments to determine the best temperature in which such transplants should be kept until they were used.

Axhausen [8] reports the results of a number of experiments in which free transplants of bone with periosteum and endosteum were transplanted from one individual to another individual of the same species. The animals used for these experiments were rats, cats and dogs. The transplants were all placed in the soft tissues, and the animals in which the transplants were placed were allowed to live for relatively short periods. The end-results of the transplantations were determined by microscopic study. In these experiments Axhausen found that the homogenous bone transplants regenerated bone. He states that the regeneration of bone is not so noticeable as in instances in which the transplantations were done in the same individual. Axhausen also found that bone grew from transplants removed from animals which had been dead for as long as thirty hours when they were placed in a living individual of the same species.

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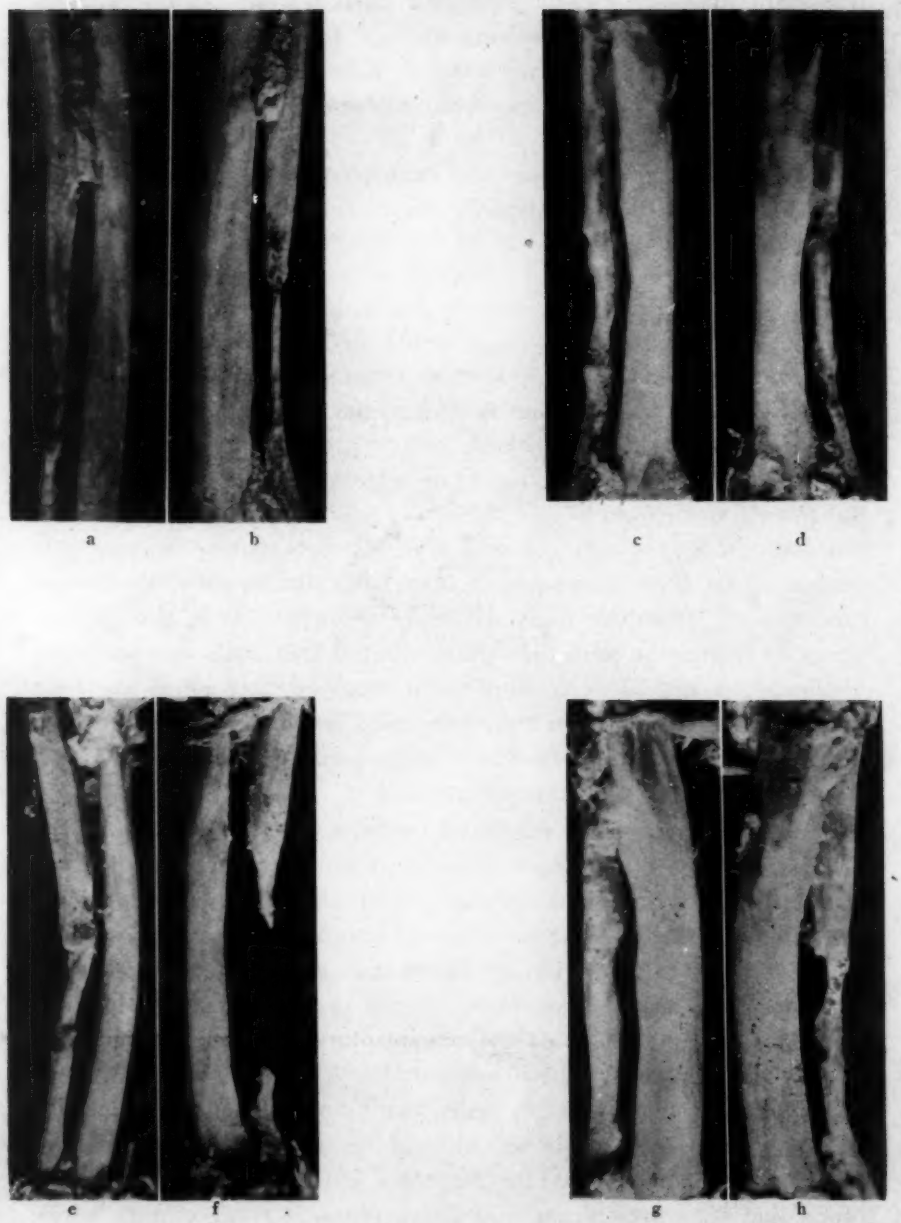
7. Ollier: Traité expérimental et clinique de la regeneration des os, Paris, 1867.

PLATE II



Transplants: *a*, autogenous, *b*, hemogenous, Experiment 21 A; *c*, autogenous, *d*, homogenous, Experiment 21 B; *e*, autogenous, *f*, homogenous, Experiment 23 A; *g*, autogenous, *h*, homogenous, Experiment 23 B.

Lexer [8] has also reported successful transplantations of bone from one individual to another individual of the same species in his transplantations of entire joints. The success of such extensive transplantations, however, has not been sufficiently convincing to lead to subsequent use of this formidable procedure. Macewen [9] describes a clinical instance in which a defect in the shaft of the humerus of a child 3 years old was successfully regenerated by transplants of bone from the tibia of another child 6 years old. Lexer reports successful regeneration of bone defect in man from the use of pieces of bone removed from the freshly amputated limbs of other individuals.

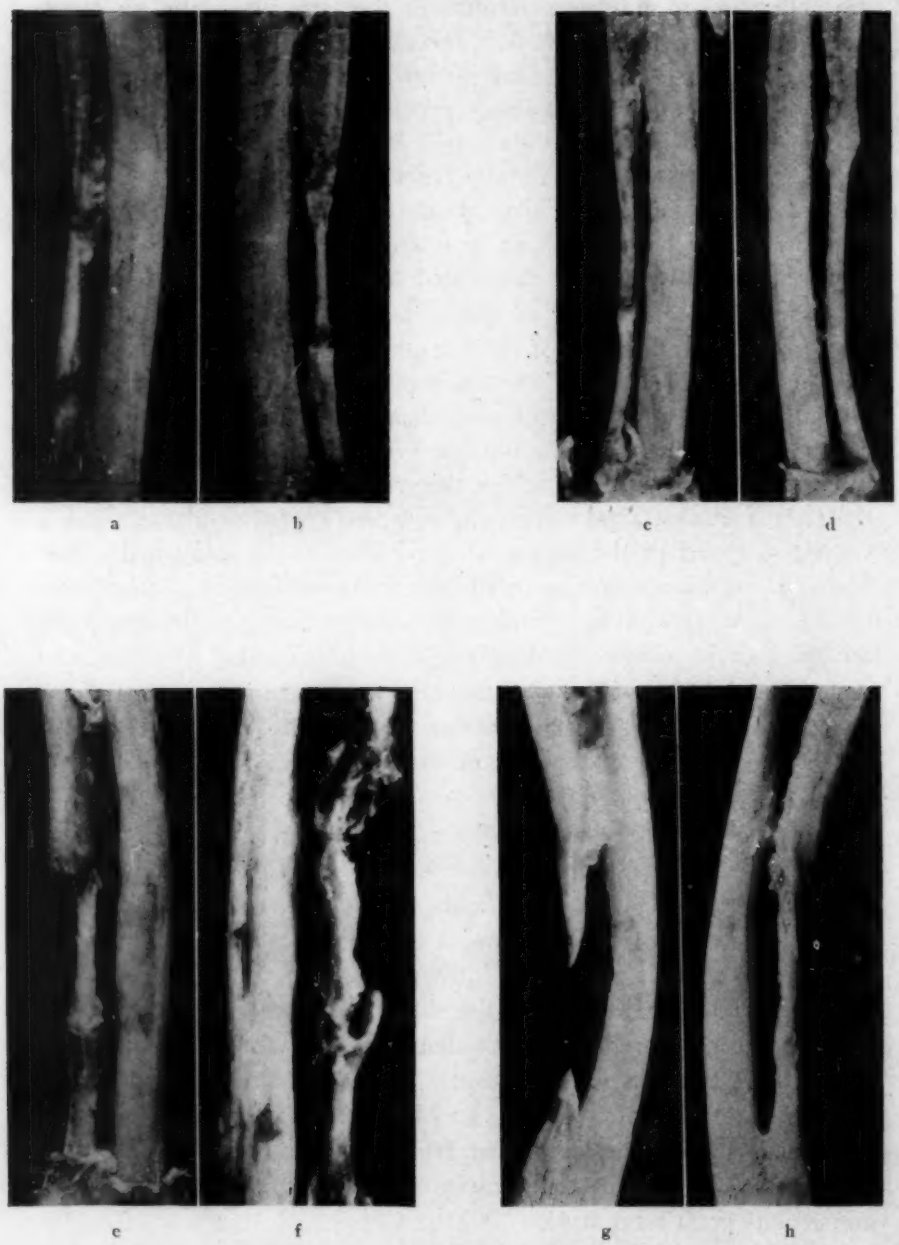
From the experiments of Ollier and Axhausen it would seem, therefore, that transplants of periosteum or bone and periosteum from one individual to another of the same species resulted in some instances in the survival of parts of the transplant and subsequent regeneration of bone. There is no experimental evidence, however, to show the proportion of instances in which this result followed. Furthermore, the mere fact that a transplant survives and regenerates tissue is not conclusive proof of the continued survival of the transplanted tissue. It may happen that a transplant of bone from one individual to another of the same species lives and grows for a time and subsequently atrophies or is completely absorbed. The experiments of Ollier and Axhausen were not of sufficient duration to test the permanency of the transplant. Also the transplantations were all into soft tissues, and it is known that even transplants of bone into soft parts in the same individual ultimately disappear.

Another problem, which has been suggested in a previous publication,[6] seemed worth experimental study. It has been shown that autogenous transplants of bone and periosteum result in failure in a considerable proportion of instances if the experimental animals are advanced in age. It was found further that the proportion of successful regenerations of defects in the shafts of bones in old dogs could be increased by a preliminary stimulation of growth in the bone from which the transplant was removed. It would seem possible with a defect in the shaft of a bone in an old dog that such a defect might be bridged by a transplant taken from a young dog with a greater chance of a successful regeneration of the bone defect than if an autogenous graft were used.

The experiments described in this paper were therefore undertaken for the purpose of studying the following problems:

8. Lexer: Arch. f. klin. Chir. **86**:939, 1908; ibid. **90**:263, 1909.
9. Macewen: The Growth of Bone, Glasgow, James Maclehose and Sons, 1912.

PLATE III



Transplants: *a*, autogenous, *b*, homogenous, Experiment 24 A; *c*, autogenous, *d*, homogenous, Experiment 24 B; *e*, autogenous, *f*, homogenous, Experiment 25 A; *g*, autogenous, *h*, homogenous, Experiment 25 B.

1. Is it possible to regenerate, permanently, a defect in the shaft of a bone by bridging this defect with a bone transplant taken from another individual of the same species?

2. In what proportion of instances may a successful result be expected?

3. What is the influence of the ages of the donor and recipient on the proportions of success and failure of homogenous bone transplants?

EXPERIMENTAL METHOD

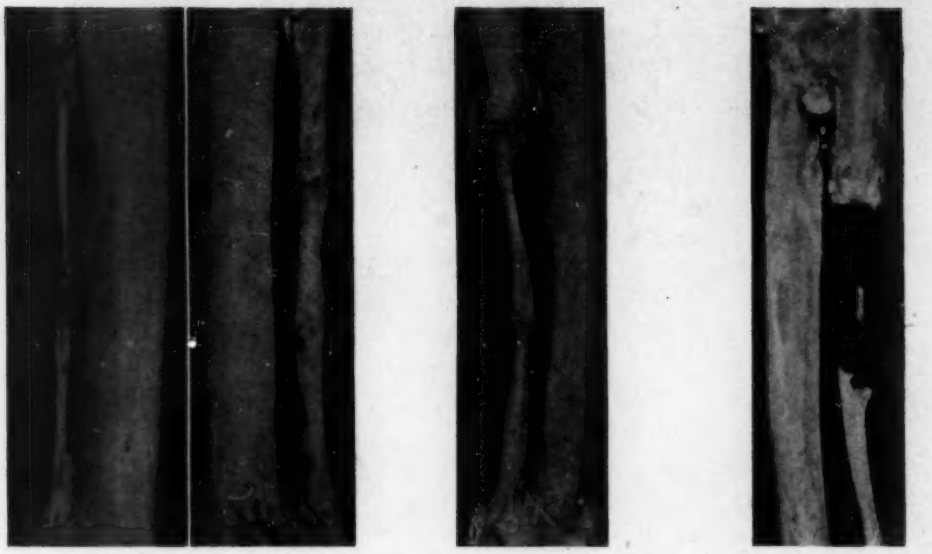
Dogs were used in all experiments. The operative procedures were carried out with the animals in complete surgical anesthesia. Careful aseptic precautions were taken. In only a few instances did wound infection occur. Those animals which did not die were sacrificed by the administration of chloroform.

The animals were operated on in pairs. An attempt was made to have, as often as available material permitted, each pair an old dog and a young dog. The animals were anesthetized and both forelegs of each animal were prepared for operation. A segment of each ulna from 2.5 to 4 cm. in length with all periosteum was excised. It is to be emphasized that in order for the segment of bone to be removed with all its periosteum, the interosseous membrane between the radius and ulna must be divided with a knife before the resection is begun. A large number of experiments have shown that such a defect will not regenerate without the use of some sort of transplant. One of the defects in each animal was then bridged by an autogenous transplant with its periosteum and endosteum. The other defect in the ulna of each dog was bridged by a homogenous transplant. The homogenous transplants were exchanged between the two animals.

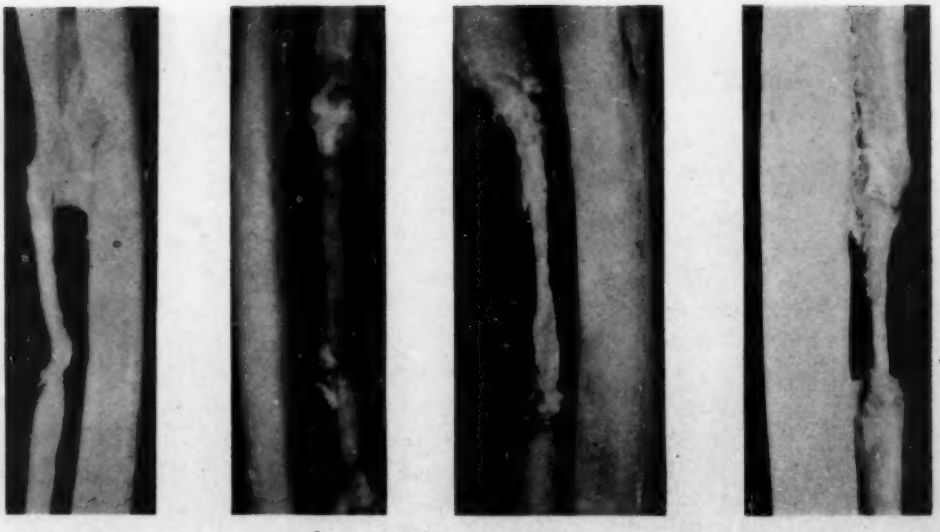
The transplants were in some experiments obtained by cutting a strip of bone from the shaft of the femur with a motor saw. In these instances a strip of bone from 6 to 8 cm. long was cut and subsequently divided. One piece was used as a transplant in the defect in the ulna of the same dog, and the other piece was used to bridge the defect in the ulna of the other animal. In other experiments the transplants were made from the excised segments of the ulnae of the two animals used at each operation. In these cases the segment of the ulna of each animal was split longitudinally; one half was used as an autogenous transplant and the other half as a homogenous transplant. The autogenous transplants were always changed from right to left, or left to right, so that in no case were they simply excised and replaced in the same bed.

This operative procedure gave in each animal two transplants in similar defects in each ulna. One transplant was an autogenous graft and the other a homogenous graft.

PLATE IV



a b c d



e f g h

Transplants: *a*, homogenous, *b*, autogenous, Experiment 26 B; *c*, homogenous, Experiment 20 A; *d*, homogenous, Experiment 20 B; *e*, homogenous, Experiment 19 A; *f*, homogenous, Experiment 17 B; *g*, homogenous, Experiment 17 A; *h*, homogenous, Experiment 16 B.

After the bone transplants had been snugly placed in the defects in the ulnae the wounds were carefully closed. The skin was always sutured with a cuticular stitch. A dry gauze dressing was applied which usually remained in good condition for twenty-four hours, after which time the operative wounds required no further attention. The animals always began, immediately after recovery from the anesthetic, to use their legs, and the dogs always used their legs apparently with no discomfort.

Beginning in the second week after operation, in some of the experiments, the animals were given twice each week an intraperitoneal injection of 2 c.c. of a saturated aqueous solution of sodium alizarin sulphonate, which has been shown by previous experimental work to be a specific vital stain for growing bone. In the experiments in which it was intended that the animal live for a long period of time, these injections were not given for the reason that frequent injection of this dye frequently results in infection and death of the experimental animal. Also, in the animals which were allowed to live for long periods the vital stain would have added little to the experiment, as in these cases the successful regeneration of the bone defect or the complete failure of the transplantations were the only results to be obtained. In the experiments in which the transplants were studied at the end of shorter periods, it was important to determine the amount and exact location of bone regeneration. For this the vital staining of the growing bone is the ideal method of study, since it makes plainly visible all new bone formed during the period in which the dye was given.

At the expiration of each experiment the bones of the forelegs and one femur were removed and placed in 10 per cent. liquor formaldehydi. After the tissues had hardened, the soft tissues were carefully dissected away and the transplants were studied macroscopically and in some experiments microscopically. The femur from each animal was also cleaned of soft parts and the distal half of the femur was split longitudinally.

From the study of the general appearance of the animal and the longitudinal section of the femur, the age of the animal can be estimated approximately. At least from this study an animal may be classified as "young," "adult" or "old." If the dog had the well known characteristics of a "puppy" and the epiphyseal cartilage was still present at the distal end of the femur, the animal was classed as young. If the dog showed gray hairs about the mouth, the teeth markedly worn away, and the bones hard and brittle, with no trace of the junction between the epiphysis and diaphysis at the distal end of the femur, the animal was classified as "old." Dogs which did not show either of these extreme conditions were classified as adult. Great difficulty was

encountered in obtaining "old" dogs. No new-born puppies were used, as the high mortality of very young dogs in laboratory captivity makes it quite impossible to make use of such material without special provisions for the care of such animals.

Experiment 1 A.—Young dog. Oct. 10, 1919.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant removed from left ulna. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 1 B.

October 22; twelve days: Animal died of peritonitis following injection of alizarin red. Wound in right foreleg healed per primam. Slight discharge from wound in left foreleg. Examination of femur showed animal was a young dog.

Right ulna: Autogenous transplant in good position. Apparently slight infection at one end of transplant. Large amount of bone regeneration on both the periosteal and marrow surfaces.

Left ulna: Homogenous transplant removed from young dog. In good position. Firm fibrous union of ends of transplant and stumps of bones. New bone formation on both periosteal and marrow surfaces of transplant.

Experiment 1 B.—Young dog. Oct. 10, 1919.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by an autogenous transplant from right ulna. Defect in right ulna bridged by a homogenous transplant from ulna of young dog used in Experiment 1 A.

November 10; thirty days: Animal died of peritonitis following injection of alizarin red. Examination of femur showed animal was a young dog. Wounds in foreleg healed per primam.

Left ulna: Autogenous transplant in good position. United to stumps of resected ulna. Large amount of new bone formation from transplant.

Right ulna: Homogenous transplant removed from young dog. Transplant entirely absorbed. No regeneration of bone in defect.

Experiment 2 A.—Young dog. Oct. 18, 1919.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by an autogenous transplant from right ulna. Defect in right ulna bridged by a homogenous transplant taken from ulna of dog used in Experiment 2 B.

October 25; seven days: Dog was found dead in cage. Wound in right foreleg healed per priman. Wound in left foreleg discharging. Examination of femur showed animal was a young dog.

Left ulna: Autogenous transplant lay loose in a cavity containing purulent fluid. It was obviously completely necrotic.

Right ulna: Homogenous transplant removed from adult dog. Transplant in fairly good position. Adherent to surrounding soft tissues. Microscopic examination shows areas in transplant in which cells stain normally. The duration of the experiment was too short for regeneration to have become apparent.

Experiment 2 B.—Adult dog. Oct. 18, 1919.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by an autogenous transplant. Defect in left ulna bridged by a homogenous transplant taken from young dog of Experiment 2 A.

December 2; forty-five days: Animal given alizarin red intraperitoneally. Died of peritonitis. Wound in right foreleg healed per primam. Wound in left foreleg discharging. Examination of femur showed animal was an adult dog.

Right ulna: Autogenous transplant in fairly good position. New bone formation was found along both the periosteal and marrow surfaces of the transplant. More growth on the marrow surface.

Left ulna: Homogenous transplant had completely disappeared. There was an abscess cavity between the stumps of the resected ulna.

Experiment 3 A.—Young dog. Oct. 22, 1919.

Resection of 3 cm. of both ulnae. Defect in right ulna bridged by an autogenous transplant. Defect in left ulna bridged by a homogenous transplant removed from a young dog used in Experiment 3 B.

November 15; twenty-three days: Found dead. Cause of death not known. Wound in left foreleg healed per primam. Small sinus in scar of operation on right foreleg. Animal received two intraperitoneal injections of alizarin red. Examination of bones showed the animal was a young dog.

Right ulna: Autogenous transplant in good position. Slight infection about one end of transplant. There was a large amount of new bone formation along the entire length of the transplant.

Left ulna: Homogenous transplant in good position. Marked new bone formation along the entire transplant.

Experiment 3 B.—Young dog. Oct. 22, 1919.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by an autogenous transplant. Defect in right ulna bridged by a homogenous transplant taken from ulna of young dog used in Experiment 3 A.

November 15; twenty-three days: Animal found dead. Cause of death not known. Wounds healed per primam. Examination of bones showed animal was a young dog.

Left ulna: Autogenous transplant in good position. New bone formation along entire length of graft.

Right ulna: Homogenous transplant in good condition. Marked new bone formation from the entire length of the transplant.

Experiment 4 A.—Young dog. Dec. 4, 1919.

Resection of 3 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant removed from right ulna. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 4 B.

January 2, 1920; twenty-nine days: Animal found dead; cause of death not known. Wounds healed per primam. Examination of femur showed animal was a young dog.

Left ulna: Autogenous transplant in good position. United to stumps of resected ulna by fibrous tissue. Parts of transplant viable. Small amount of new bone from transplant.

Right ulna: Homogenous transplant in good position. United by fibrous tissue to stumps of resected bone. Microscopic examination shows parts of transplants viable with small areas of proliferation of the periosteum with formation of osteoid tissue.

Experiment 4 B.—Adult dog. Dec. 4, 1919.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant taken from left ulna. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 4 A.

Jan. 7, 1920; thirty-four days: Animal given vital stain. Wounds healed per primam. Cause of death not known. Examination of femur showed animal was an adult dog.

Right ulna: Autogenous transplant in good position. Firm union between ends of transplant and stumps of ulna. There was a large amount of new bone formed on both the periosteal and marrow surfaces of the transplant.

Left ulna: Homogenous transplant entirely absorbed and replaced by fibrous tissue. There was a large amount of new bone formed on the stumps of ulna.

Experiment 5 A.—Young dog. Dec. 9, 1919.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 5 B.

Jan. 7, 1920; twenty-nine days: Animal received alizarin red intraperitoneally. Wounds healed per primam. Cause of death not known. Examination of femur showed animal was a young dog.

Left ulna: Autogenous transplant in place and united to stumps of ulna. Microscopic examination shows transplant apparently entirely viable. Large amount of growth of new bone from transplant.

Right ulna: Homogenous transplant in place. United with stumps of ulna. Microscopic examination showed areas of the transplant viable. There was one area of definite new bone formation from transplant.

Experiment 5 B.—Old dog. Dec. 9, 1919.

Animal died of anesthetic during operation. Examination of femur showed animal was an old dog.

Experiment 6 A.—Young dog. Oct. 28, 1919.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 6 B.

December 3; thirty-six days: Animal received injections of alizarin red intraperitoneally. Wounds healed per primam. Cause of death not known. Examination of femur shows animal to be a young dog.

Right ulna: Autogenous transplant in good position united with stumps of ulna and new bone formed on all surfaces. Stumps of ulna show fair growth of new bone.

Left ulna: Homogenous transplant in place. Union with stumps of ulna not firm so that transplant was loosened in cleaning. Shows new bone formed on ends of transplant and especially on marrow surface and periosteal surface at distal end.

Experiment 6 B.—Old dog. Oct. 28, 1919.

Dog died of the anesthetic during operation. Examination of the femur showed animal was an old dog.

Experiment 7 A.—Young dog. March 16, 1920.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 7 B.

April 4; nineteen days: Animal received injections of alizarin red intraperitoneally. Wounds healed per primam. Cause of death not known. Examination of femur showed animal was a young dog.

Left ulna: Autogenous transplant in place. Very small amount of new bone formation from transplant. Stumps of ulna showed a moderate amount of new bone formation.

Right ulna: Homogenous transplant in good position. Firm union with stumps of ulna. Marked new bone formation on all surfaces of transplant. Moderate amount of new bone formed on stumps of ulna.

Experiment 7 B.—Young dog. March 16, 1920.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 7 A.

April 19; thirty-four days: Animal received alizarin red. Wounds healed per primam. Sacrificed. Examination of femur showed animal was a young dog.

Right ulna: Autogenous transplant in place, held firmly by tough fibrous tissue. About middle of marrow surface was one small island of new bone, otherwise there was no evidence of new bone formation.

Left ulna: Homogenous transplant in good position and firmly united to stumps of ulna. There was a growth of new bone on both periosteal and marrow surfaces.

Experiment 8 A.—Adult dog. March 17, 1920.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by an autogenous transplant. Defect in left ulna bridged by a homogenous transplant from dog used in Experiment 8 B.

April 19; thirty-three days: Animal received injections alizarin red intraperitoneally. Wounds healed per primam. Sacrificed and examination of femur showed animal was an adult dog.

Right ulna: Autogenous transplant in place. Union at distal end with stump of ulna by new bone. Proximal end showed little bone formation. Over periosteal and marrow surfaces was a fair amount of new bone. Stumps of ulna showed marked new bone formation.

Left ulna: Homogenous transplant in good position united with stumps of ulna by fibrous tissue. On periosteal surface of transplant was a small amount of new bone, while marrow surface showed no new bone formation. Moderate amount of new bone formed on the stumps of the ulna.

Experiment 8 B.—Adult dog. March 17, 1920.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant from left ulna. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 8 A.

April 4; eighteen days: Animal died of peritonitis following intraperitoneal injection of alizarin red. Both wounds wide open, right discharging pus. Examination of femur showed animal was an adult dog.

Right ulna: Autogenous transplant lost. Stumps of ulna protruding from open wound.

Left ulna: Homogenous transplant in good position, fair amount of new bone formed on both periosteal and marrow surfaces but no union with stumps of ulna. Pus pocket about transplant.

Experiment 9 A.—Old dog. March 19, 1920.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant from the right ulna. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 9 B.

April 6; eighteen days: Animal died of peritonitis following intraperitoneal injection of alizarin red. Wounds healed per primam. Examination of femur showed animal was an old dog.

Left ulna: Autogenous transplant in good position. Held and covered by fibrous tissue. No new bone formation.

Right ulna: Homogenous transplant in good position. Held by fibrous tissue. Considerable new bone formed on periosteal and marrow surfaces.

Experiment 9 B.—Young dog. March 19, 1920.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant from left ulna. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 9 A.

April 18; thirty days: Animal sacrificed, received alizarin red. Wounds healed per primam and examination of femur showed animal was a young dog.

Right ulna: Autogenous transplant held in good position by fibrous tissue. New bone formation on both periosteal and marrow surfaces, especially at the proximal end.

Left ulna: Homogenous transplant in good position. United firmly with stumps of ulna by fibrous tissue. There was a marked new bone formation on all surfaces, especially on the periosteal surface facing the radius.

Experiment 10 A.—Young dog March 22, 1920.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant from right ulna. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 10 B.

April 21; thirty days: Animal sacrificed, received alizarin red. Wounds healed per primam. Examination of femur showed animal was a young dog.

Left ulna: Autogenous transplant position very good. Union with stumps of ulna firm and there was a growth of new bone on both periosteal and marrow surfaces of transplant.

Right ulna: Homogenous transplant slightly overriding proximal stump of ulna, union of a fibrous tissue nature with some new bone formation. Union with distal stump firm. Both periosteal and marrow surfaces showed a small amount of new bone formation.

Experiment 10 B.—Adult dog. March 22, 1920.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant from left ulna. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 10 A.

April 21; thirty days: Animal sacrificed. Received injections of alizarin red intraperitoneally. Wounds healed per primam. Examination of femur showed animal was an adult dog.

Right ulna: Autogenous transplant in good position. Union with distal stump of ulna firm, with proximal stump fibrous. Extensive formation of new bone on marrow surface. On periosteal surface small amount of new bone.

Left ulna: Homogenous transplant in good position. No new bone formation. Transplant apparently was being rapidly absorbed.

Experiment 11 A.—Young dog. March 23, 1920.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant from right ulna. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 11 B.

April 7; fourteen days: Animal died of peritonitis following intraperitoneal injection of alizarin red. Wounds healed per primam. Examination of femur showed animal was a young dog.

Left ulna: Autogenous transplant in place. Along medial edge of defect in ulna was a small portion of the ulna which was about 3 mm. in diameter which had been separated from ulna at distal end; but was connected at proximal

end by a bridge of bone about 1 mm. in diameter. Along marrow surface of transplant where it was closely related to this segment of bone, there was marked new bone formation.

Right ulna: Homogenous transplant united with both stumps of ulna by fibrous tissue. Small amount of new bone formed on marrow surface.

Experiment 11 B.—Adult dog. March 23, 1920.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant from left ulna. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 11 A.

April 21; twenty-nine days: Animal sacrificed. Received injections of alizarin red intraperitoneally. Wounds healed per primam. Examination of femur showed animal was an adult dog.

Right ulna: Autogenous transplant in good position. Union with distal stump of ulna firm, with proximal stump fibrous. Over whole surface of transplant and the stumps of the ulna was an enormous amount of callous formation. About the transplant were areas of a thick gelatinous fluid suggesting mild infection.

Left ulna: Homogenous transplant in good position. United to stumps of ulna by fibrous tissue. Small amount of new bone formed on periosteal surface of transplant.

Experiment 12 A.—Young dog. March 24, 1920.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 12 B.

April 22; twenty-nine days: Animal sacrificed. Received injections of alizarin red intraperitoneally. Wound in right leg has sinus leading into deep fascia. Wound in left leg healed per primam. Examination of femur showed animal was a young dog.

Left ulna: Autogenous transplant in place surrounded by a mass of fibrous tissue. No signs of union with stumps but a good growth of new bone on all surfaces of transplant.

Right ulna: Homogenous transplant in place, surrounded by mass of mucin-like material. No signs of new bone formation.

Experiment 12 B.—Old dog. March 24, 1920.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 12 A.

April 6; thirteen days: Animal died of peritonitis following injection of alizarin red. Wound in left leg open. Wound in right leg healed per primam. Examination of femur showed animal was an old dog.

Right ulna: Autogenous transplant in place. No union, but a small amount of new bone on middle of outer periosteal surface of transplant.

Left ulna: Homogenous transplant lost through the open wound.

Experiment 13 A.—Adult dog. March 25, 1920.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 13 B.

April 24; thirty days: Animal sacrificed. Received injections of alizarin red intraperitoneally. Wound in right leg healed per primam. That in left leg had skin open but no discharge. Examination of femur showed animal was an adult dog.

Left ulna: Autogenous transplant not found. On distal stump of ulna was considerable callous formation, with fibrous tissue bridging defect. No evidence of infection about bed of transplant.

Right ulna: Homogenous transplant in good position. Firm fibrous union with stumps of ulna. On marrow surface of transplant was a narrow border of new bone extending the full length of the transplant. On the lateral surface, which is the periosteal, there was a small amount of new bone at the ends of the transplant.

Experiment 13 B.—Adult dog. March 25, 1920.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 13 A.

April 2; eight days: Animal dead in cage, cause not known. Received one injection of alizarin red intraperitoneally. Wounds healed per primam. Examination of femur showed animal was an adult dog.

Right ulna: Autogenous transplant in place. Microscopic study shows normal staining of the cells in the greater part of the transplant. No regeneration found. Duration of experiment was too short to determine definitely whether regeneration would have resulted.

Left ulna: Homogenous transplant in place. Microscopic study shows greater part of transplant viable. There was active regeneration of osteoid tissue from the marrow surface of the transplant.

Experiment 14 A.—Adult dog. March 26, 1920.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 14 B.

April 24; twenty-nine days: Animal sacrificed. Received alizarin red. Wounds healed per primam. Examination of femur showed animal was an adult dog.

Left ulna: Autogenous transplant in good position. United with stumps by fibrous tissue. Only a small amount of new bone formed on proximal stump, with slight amount of new bone on proximal end of transplant.

Right ulna: Homogenous transplant held in good position by firm fibrous union with stumps of ulna. There was a small amount of new bone formed along the marrow surface of the transplant.

Experiment 14 B.—Adult dog. March 26, 1920.

Resection of 2.5 cm. of both ulnae. Defect in right ulna bridged by autogenous transplant. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 14 A.

April 4; nine days: Animal found dead in cage, cause of death not known. Examination of femur showed animal was an adult dog.

Transplants not studied.

Experiment 15 A.—Old dog. Feb. 12, 1918.

Resection of 4 cm. of shaft of right ulna. Defect in bone bridged by a homogenous transplant of bone and periosteum removed from the shaft of femur of the dog used in Experiment 15 B.

March 28; forty-four days: Wound healed without infection. Animal in good health. Was given injections of sodium alizarin sulphonate twice each week. Sacrificed.

Examination of the bones indicated that the animal was an old dog. The homogenous transplant was removed from a young dog. The transplant was in good position. There was very little growth of bone from the stumps of

the resected bone. The transplant showed no evidence of regeneration of bone. There was, however, distinct evidence of absorption of the graft. The transplant was adherent to the surrounding tissues. Microscopic examination of the transplant showed no part of the transplant viable, and evident absorption of the transplant.

Experiment 15 B.—Young dog. Feb. 12, 1918.

Resection of 4 cm. of shaft of ulna. Defect bridged by a transplant of bone and periosteum removed from the femur of the dog used in Experiment 15 A.

February 24; twelve days: Wounds healed without infection. Animal in poor health. Sacrificed. Examination of bones shows animal to be a young dog. The transplant in the defect in the ulna was removed from an old dog. The transplant was in good position. Gross and microscopic examination showed no evidence of regeneration of tissue from the transplant. There were no living cells in any part of the transplant

Experiment 16 A.—Old dog. March 26, 1918.

Resection of 4 cm. of ulna with periosteum. Defect bridged by a homogenous transplant from the femur of adult dog used in Experiment 16 B.

April 18; thirteen days: Animal died from pneumonia. Wounds healed without infection. Examination of femur indicated that animal was an old dog. Microscopic examination of the transplant showed small areas on the marrow side of the transplant in which there was proliferation of cells apparently from the endosteum of the transplant. Also small sections of the periosteum were apparently viable. The transplanted cortical bone was apparently completely necrotic.

Experiment 16 B.—Adult dog. March 26, 1918.

Resection of 4 cm. of ulna. Defect bridged by a homogenous transplant removed from the femur of old dog used in Experiment 16 A.

June 4; seventy days: Animal in good health. Wounds healed without infection. Examination of bones indicated that animal was an old dog. The homogenous transplant was in good position. It is firmly united to the stumps of the resected bone. The transplant had increased very little in thickness. There was very little bone regeneration from the stumps of the resected bone. The defect was completely bridged by viable bone but the growth of bone from the transplant had been very slow.

Experiment 17 A.—Adult dog. Feb. 4, 1918.

Resection of 4 cm. of right ulna with periosteum. Defect bridged by a homogenous transplant removed from femur of adult dog used in Experiment 17 B.

April 5; sixty days: Wounds healed without infection. Animal in good health. Sacrificed. Examination of femur indicated that the animal was an adult dog. The stumps of the resected bone were joined by a thin fibrous cord in which lay a thin remnant of the bone transplant. There was no evidence of regeneration from the transplant. It was obviously in process of being absorbed.

Experiment 17 B.—Adult dog. Feb. 4, 1918.

Resection of 4 cm. of right ulna with periosteum. Defect bridged by a homogenous transplant from femur of adult dog used in Experiment 17 A.

April 5; sixty days: Wounds healed without infection. Animal in good health. Sacrificed. Femur showed animal to be an adult dog. The homogenous transplant was united to the stumps of the resected bone. There was regeneration of bone along the entire length of the transplant. The amount of growth of the graft was rather small.

Experiment 18 A.—Adult dog. Jan. 9, 1917.

Resection of 3 cm. right ulna. Bone transplant 3 cm. long, 2 mm. broad cut from full thickness of cortex of shaft of femur. This transplant was used in Experiment 18 B. The defect in the right ulna was bridged by a homogenous transplant removed from femur of dog used in Experiment 18 B.

March 16; fifty-eight days: Wounds healed per primam. Animal given alizarin red intraperitoneally. Dog died of peritonitis. Examination of bones indicated that animal was an adult dog. Very little regeneration of bone in the defect in the femur from which transplant for Experiment 18 B was removed.

The homogenous transplant in the defect in the ulna was in good position. The proximal end of graft was firmly united to the proximal stump of the resected bone. There was no union between the distal end of the transplant and the distal stump of the resected ulna. There was marked growth of bone from the proximal two thirds of the transplant. None from the distal third. There was very little bone growth from the proximal stump of the ulna.

Experiment 18 B.—Young dog. Jan. 9, 1917.

Resection of 4 cm. of right ulna. Bone transplant with periosteum and endosteum removed from shaft of femur and used in Experiment 18 A. Defect in right ulna was bridged by a homogenous transplant removed from dog used in Experiment 18 A.

February 28; fifty days: Wounds healed per primam. Dog was given alizarin red intraperitoneally. Sacrificed. Examination of bones showed animal to be a young dog. Defect in the femur from which transplant for Experiment 18 A filled by new bone.

Homogenous transplant in defect in ulna in good position. No evidence of any growth of bone from transplant. The transplant was embedded in fibrous tissue to which it was intimately attached. The transplant was clearly in porcess of absorption. There was a large amount of bone regeneration from the stumps of the resected bone.

Experiment 19 A.—Old dog. April 1, 1918.

Resection of 4 cm. of ulna. Defect bridged by a homogenous transplant removed from the femur of old dog used in Experiment 19 B.

June 4; sixty-four days: Animal in good condition. Wounds healed without infection. Sacrificed. Examination of femur showed animal to be an old dog. The homogenous transplant in the ulna defect was in good position. It was firmly united to the proximal stump of the ulna. The union of the transplant and the distal stump was fibrous. The transplant was viable. It was only very slightly increased in thickness.

Experiment 19 B.—Old dog. April 1, 1918.

Resection of 4 cm. of ulna. Defect bridged by a homogenous transplant removed from the femur of old dog used in Experiment 19 A.

April 8; seven days: Animal died of pneumonia. Wounds healed without infection. Examination of bones indicated that animal was an old dog. Transplant removed for microscopic study. Microscopic examination showed areas in the transplant in which the cells stained in a normal manner. There was no evidence of growth of tissue from the transplant.

Experiment 20 A.—Adult dog. Feb. 2, 1918.

Resection of 4 cm. of shaft of ulna. The defect was bridged by a transplant of bone and periosteum removed from the femur of the dog in Experiment 20 B.

May 15; 102 days: Animal given injections of sodium alizarin sulphonate once each week. Has remained in good health. Sacrificed. Examination of bones of dog indicated that the animal was an adult dog. The transplant was in good position. It was firmly united to the stumps of the resected bone. There was growth of bone along the entire length of the transplant.

Experiment 20 B.—Young dog. Feb. 2, 1918.

Resection of 4 cm. right ulna with periosteum. Defect bridged by a bone transplant removed from femur of adult dog used in Experiment 20 A.

May 15; 102 days: Wound healed without infection. Animal in good health. Examination of femur showed animal to be a young dog. The homogenous transplant bridging the defect in ulna had completely failed to regenerate the defect. The graft was all absorbed except a small piece.

Experiment 21 A.—Adult dog. March 20, 1919.

Resection of 4 cm. of shafts of both ulnae. Defect in right ulna bridged by an autogenous transplant from left ulna. Defect in left ulna bridged by a homogenous transplant from the ulna of dog used in Experiment 21 B.

September 25; 189 days: Wounds healed without infection. No vital stain given. Animal remained in good health. Sacrificed. Examination of femur indicated that animal was an adult dog.

Right ulna: Autogenous transplant. The defect was entirely bridged by bone. The transplanted area was very slightly smaller than the normal bone. The junction of the transplant and distal stump of resected bone was plainly visible. The junction of the transplant and the proximal stump could not be seen.

Left ulna: Homogenous transplant. Removed from adult dog. The defect was completely bridged by bone. The transplanted area was, however, approximately half the diameter of the normal bone. The junction of the transplant and the proximal stump was plainly visible.

Experiment 21 B.—Adult dog. March 20, 1919.

Resection of 4 cm. of shafts of both ulnae. Defect in right ulna bridged by autogenous transplant from left ulna. Defect in left ulna bridged by a homogenous transplant from dog used in Experiment 21 A.

August 8; 141 days: Wounds healed without infection. Vital stain given. Animal died. Examination of femur showed that animal was an adult dog.

Right ulna: Autogenous transplant in good position. Firmly united to both stumps of resected bone. Junctions of transplants and stumps of ulna distinct. Transplanted area successfully repaired.

Left ulna: Homogenous transplant. Removed from adult dog. Graft in good position. Firmly united to stumps of resected bone. Transplanted area almost identical with that of right ulna.

Experiment 22 A.—Old dog. Oct. 30, 1919.

Resection of 2.5 cm. of both ulnae. Defect in left ulna bridged by autogenous transplant. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 22 B.

April 17; 170 days; Animal sacrificed. Received injections of alizarin red. Wounds healed per primam. Examination of femur showed animal to be an old dog.

Left ulna: Autogenous transplant completely absorbed and its place filled by fibrous tissue.

Right ulna: Homogenous transplant in position. Solid union with distal stumps of ulna. Proximal end of transplant slightly overlapped the proximal

stump of ulna and had a fibrous union. The defect was completely bridged by the bone, except for the fibrous union of the transplant and the proximal stump of the ulna.

Experiment 22 B.—Young dog. Oct. 30, 1919.

Animal died of anesthetic during operation. Examination of femur showed animal to be a young dog.

Experiment 23 A.—Adult dog. March 6, 1919.

Resection of 2.5 cm. of shafts of both ulnae with periosteum. The defect in the right ulna was bridged by an autogenous bone graft from the segment of bone removed from the left ulna. The defect in the left ulna was bridged by a homogenous transplant taken from the ulna of dog used in Experiment 22 B.

October 16; 224 days: Wounds healed without infection. Animal has remained in good health. No vital stain given. Sacrificed. Examination, the femur indicated that the animal was an adult dog.

Right ulna: Autogenous transplant. Graft in fairly good position. Firmly united to the stumps of the resected bone. Junction with proximal stump still visible. No trace of junction between graft and distal stump. Defect completely regenerated.

Left ulna: Graft entirely absorbed. Ends of stumps of resected bone conical. Complete failure of transplant.

Experiment 23 B.—Adult dog. March 6, 1919.

Resection of 2.5 cm. of shafts of both ulnae. Defect in right ulna bridged by an autogenous transplant from the left ulna. Defect in left ulna bridged by a homogenous graft removed from dog used in Experiment 23 A.

October 16; 224 days: Wounds healed without infection. No vital stain given. Animal remained in good health. Sacrificed. Examination of the femur showed the animal to be an adult dog.

Right ulna: Autogenous transplant. Defect completely regenerated. Regeneration so perfect that little trace of previous operative procedure was visible.

Left ulna: Homogenous transplant removed from adult dog. Graft was in good position. United to both stumps of resected bone. Transplanted area slightly smaller than normal bone. The defect was completely regenerated, but not so perfectly as in the case of the autogenous transplant.

Experiment 24 A.—Old dog. Feb. 15, 1919.

Resection of 3 cm. of both ulnae. Defect in right ulna bridged by an autogenous transplant removed from dog used in Experiment 24 B.

October 16; 243 days: Wounds healed without infection. Animal has remained in good health. No vital stain given. Sacrificed. Examination of bones indicated that animal was an old dog.

Right ulna: Autogenous transplant in good position. Firmly united to stumps of resected bone. Transplant apparently completely successful.

Left ulna: Homogenous transplant from old dog. Graft in good position. Firmly united to both stumps of resected ulna. The transplant was approximately the same size as the original bone at each end. The middle of the transplant was not so large as the original bone. The defect was apparently successfully repaired, but the growth of bone in the defect was not as marked as from the autogenous transplant.

Experiment 24 B.—Old dog. Feb. 15, 1919.

Resection of 3 cm. of both ulnae. The defect in the right ulna bridged by an autogenous transplant from the left ulna. The defect in the left ulna was bridged by a homogenous transplant removed from dog used in Experment 24 A.

October 16; 243 days: Wounds healed without infection. No vital stain given. Sacrificed. Examination of the femur indicated that the animal was an old dog.

Right ulna: Autogenous transplant. The defect was completely regenerated. The transplanted area was approximately the same size as the normal bone. The site of union of the transplant with the distal stump was plainly visible. There was no trace of the site of union of the transplant and the proximal stump of the ulna.

Left ulna: Homogenous transplant removed from old dog. Defect was completely regenerated. The area of transplantation was equal in size to the normal bone. The junction of the transplant with the proximal stump was visible.

Experiment 25 A.—Young dog. April 12, 1918.

Resection of 2.5 cm. of both ulnae. Transplant 6 cm. long cut from shaft of femur. One half of this transplant was used to bridge the defect in the right ulna. The other half was used in Experiment 25 B. The defect in the left ulna was bridged by a transplant removed from femur of dog used in Experiment 25 B.

May 31; forty-nine days: Animal dead. Cause not known. The wound in the right foreleg healed without infection. There was a small discharging sinus in the operation wound of the left foreleg. Animal was given vital stain. Examination of the bones showed the animal to be a young dog.

Right ulna: The autogenous transplant was in good position. It was firmly united to the distal stump of the ulna. The union to the proximal stump was fibrous. There was growth of bone from both stumps of the ulna and along the entire length of the transplant.

Left ulna: The homogenous transplant was in good position. There was a cavity at each end of the graft containing purulent fluid. There was a large amount of new bone formation from the transplant. The infection had apparently not extended along the transplant but was localized to the ends of the transplant.

Experiment 25 B.—Old dog. April 12, 1918.

Resection of 3 cm. of both ulnae. Transplant 6 cm. long cut from the shaft of the femur. One half of this transplant was used to bridge the defect in the right ulna. The other half was used in Experiment 25 A. The defect in the left ulna was bridged by a transplant removed from the femur of dog used in Experiment 25 A.

Jan. 22, 1919; 285 days: Animal in good condition. Wounds healed without infection. Sacrificed. Examination of the femur indicated that the animal was an old dog.

Right ulna: The autogenous transplant had completely disappeared. The stumps of the resected ulna were conical. There was a defect measuring 2 cm.

Left ulna: The homogenous transplant had completely regenerated the defect. The area of regeneration was equal in size to the stumps of the resected bone.

Experiment 26 A.—Adult dog. April 9, 1919.

Resection of 3 cm. of both ulnae. Bone graft 6 cm. long, 2 mm. wide was removed from the shaft of the femur. Periosteum preserved in the bone transplant. One half of the transplant was used to bridge the defect in the left ulna. The other half of the transplant was used in Experiment 26 B. The defect in the right ulna was bridged by a transplant from the femur of the dog used in Experiment 26 B.

April 19; ten days: Animal died of infection in thigh wound. Wounds in both forelegs healed without infection.

Microscopic examination showed both the autogenous and homogenous transplants apparently completetly necrotic. There was no demonstrable difference in reaction about the transplants.

Experiment 26 B.—Old dog. April 9, 1918.

Resection 3 cm. of both ulnae. Transplant of bone and periosteum 6 cm. long removed from shaft of femur. One half of this transplant used to bridge defect in the left ulna. The other half was used in Experiment 26 A. The defect in the right ulna was bridged by a transplant from the femur of adult dog in Experiment 26 A.

Jan. 23, 19; 290 days: Animal in good condition. Wound healed without infection. Sacrificed. Examination of bones showed the animal to be an old dog.

Left ulna: The autogenous transplant was in perfect condition. The defect in the ulna was completely regenerated. The area of regeneration was larger than the contiguous stumps of the resected bone.

Right ulna: The homogenous transplant was in perfect position. The defect was completely regenerated. The area of transplantation was equal in size to the distal stump of the resected bone. This stump of bone had, however, decreased markedly in size. The regenerated area was much smaller than the proximal stump of the ulna.

COMMENT

In the discussion of the results of these experiments only those experiments in which the experimental animals lived long enough to determine definitely the presence or absence of bone regeneration are considered.

These experiments show conclusively that a transplant of bone with the periosteum and marrow surfaces intact removed from one dog and placed in a defect in the shaft of a bone of another dog may result in a complete regeneration of the defect. The transplant in such instances remains in whole or part viable and is the source of bone regeneration. Experiments 23 B, 24 A, 24 B, 25 B and 26 B show the bone defect completely regenerated at the end of periods of seven and nine months. In Experiment 25 B, in which the animal was sacrificed 285 days after the transplantation, the repair of the defect was so perfect it is difficult to believe otherwise than that the defect is permanently repaired. In the study of the homogenous transplants of shorter duration it was clear that the transplant was the source of new bone formation. Whether the defect is permanently repaired by cells regenerated from the transplant or whether these cells are subsequently replaced by cells derived from the host is not clear.

The comparison of the proportions of success and failure of the autogenous transplants and the homogenous transplants is of particular interest. It will be noted in Table 2 that the percentage of instances in which bone regeneration took place from the homogenous transplants was not strikingly lower than that from the autogenous transplants. Furthermore in thirteen experiments in which the duration of the experiment was longer than three months the homogenous transplants

TABLE 1.—SUMMARY OF EXPERIMENTS

Exper. No.	Age of Dog	Duration of Experiment, Days	Results of Autogenous Transplant	Source of Homogenous Transplant	Age of Donor	Results of Homogenous Transplant	Remarks
1 A	Young	12	+++	1 B	Young	+++	Slight infection autogenous transplant
1 B	Young	30	+++	1 A	Young	0	Homogenous transplant completely absorbed
2 A	Young	7	—	2 B	Adult	?	Duration of experiment too short
2 B	Adult	45	+	2 A	Young	—	Homogenous transplant infected
3 A	Young	23	+++	3 B	Young	+++	
3 B	Young	23	+++	3 A	Young	+++	
4 A	Young	29	+	4 B	Adult	+	
4 B	Adult	34	+++	4 A	Young	0	Homogenous transplant completely absorbed
5 A	Young	29	+++	5 B	Old	+	
5 B	Old	0	—	—	—	—	Died of anesthetic
6 A	Young	36	+++	6 B	Old	++	
6 B	Old	0	—	—	—	—	Died of anesthetic
7 A	Young	19	+	7 B	Young	+++	
7 B	Young	34	+	7 A	Young	+++	
8 A	Adult	33	++	8 B	Adult	+	
8 B	Adult	18	—	8 A	Adult	++	Both wounds infected
9 A	Old	18	0	9 B	Young	+++	
9 B	Young	30	++	9 A	Old	+++	
10 A	Young	30	+++	10 B	Adult	+	
10 B	Adult	30	+	10 A	Young	0	
11 A	Young	14	+++	11 B	Adult	++	
11 B	Adult	29	+++	11 A	Young	+	Autogenous transplant slightly infected
12 A	Young	29	+++	12 B	Old	—	Mild infection about homogenous transplant
12 B	Old	13	+	12 A	Young	—	Homogeonus transplant infected
13 A	Adult	30	0	13 B	Adult	+	
13 B	Adult	8	?	13 A	Adult	+++	
14 A	Adult	29	+	14 B	Adult	+	
14 B	Adult	9	—	14 A	Adult	—	Transplant not examined
15 A	Old	44	—	15 B	Young	0	
15 B	Young	12	—	15 A	Old	0	
16 A	Old	13	—	16 B	Adult	+	
16 B	Adult	70	—	16 A	Old	++	
17 A	Adult	60	—	17 B	Adult	0	
17 B	Adult	60	—	17 A	Adult	+	
18 A	Adult	58	—	18 B	Young	++	
18 B	Young	50	—	18 A	Adult	0	
19 A	Old	64	—	19 B	Old	++	
19 B	Old	7	—	19 A	Old	?	
20 A	Adult	102	—	20 B	Young	+++	
20 B	Young	102	—	20 A	Adult	0	
21 A	Adult	189	+++	21 B	Adult	++	
21 B	Adult	141	+++	21 A	Adult	+++	
22 A	Old	170	0	22 B	Young	++	
22 B	Young	0	—	—	—	—	Died of anesthetic
23 A	Adult	224	+++	23 B	Adult	0	
23 B	Adult	224	+++	23 A	Adult	+++	Autogenous transplant more perfect
24 A	Old	243	+++	24 B	Old	+++	Autogenous transplant more perfect
24 B	Old	243	+++	24 A	Old	+++	Homogenous transplant more perfect
25 A	Young	49	+++	25 B	Old	+++	
25 B	Old	285	0	25 A	Young	+++	
26 A	Adult	10	0	26 B	Old	0	
26 B	Old	290	+++	26 A	Adult	++	

TABLE 2.—RESULTS OF TRANSPLANTATIONS

		Success	Failure	Per Cent. Success
Total number transplants	76	61	15	80.2
Autogenous transplants	33	28	5	84.8
Homogenous transplants	43	33	10	76.8

resulted in actually a larger percentage of successful regenerations of the bone defects than the autogenous transplants. This indicates that the survival and growth of the transplant is not merely temporary. In thirty-one experiments the results of both autogenous and homogenous transplants were observed in the same animals for the same periods of time. In one instance both the autogenous and homogenous transplants failed. In four instances the autogenous transplant alone failed. In five instances the homogenous transplant alone failed. In the remaining twenty-one instances, in which there was growth of bone from both transplants, there was no noticeable difference in the amount of growth of bone from the two transplants in ten experiments. In eight instances the autogenous transplants regenerated more bone, and in three instances the homogenous transplants grew better. It would seem, therefore, that homogenous transplants of bone are less likely to succeed than autogenous transplants, but that there is no indication that homogenous transplants grow for a time and then

TABLE 3.—Results of Autogenous Transplants

Age	Number	Success	Failure	Per Cent. Success
Young	14	14	0	100
Adult	12	10	2	83
Old	7	4	3	57

become absorbed. Furthermore, the relative percentages of success of the autogenous and homogenous bone transplants are not strikingly different.

The influence of the ages of the experimental animals on the proportions of success and failure of the autogenous transplants is clearly shown in Table 3. These results in the autogenous transplants correspond exactly with our previous experience. There was no instance in which regeneration did not take place from an autogenous transplant in a young animal in which wound infection did not occur. In the old animals the percentage of instances in which regeneration from the autogenous transplant was found decreased to 57 per cent. The autogenous transplants served as a control of the method of experimental study of the homogenous transplants, since both types of transplants were similarly placed in the same animals and the results observed at the same intervals of time.

The relative ages of the donors and recipients of the homogenous transplants is shown in Tables 4, 5 and 6. In Table 4 the number of different combinations of ages of donors and recipients is so large that the number of experiments in each combination is small. The per-

centage of success of the homogenous transplants in the various combinations of ages of donor and recipient is strikingly equal in all the various combinations except in the groups of old donor-adult recipient (50 per cent.), adult donor-old recipient (100 per cent.) and old donor-old recipient (100 per cent.). In these groups the number of experiments in each was small. In Table 5 the ages of the donors independent of the ages of the recipients is shown. It will be noted that the young donors gave a smaller proportion of successful homogenous

TABLE 4.—RESULTS OF HOMOGENOUS TRANSPLANTS IN THE VARIOUS COMBINATIONS OF AGES OF DONORS AND RECIPIENTS

Donor	Recipient	Number	Success	Failure	Per Cent. Success
Young	Young	6	5	1	83
Adult	Young	5	4	1	80
Old	Young	5	4	1	80
Young	Adult	5	3	2	60
Adult	Adult	11	9	2	81
Old	Adult	2	1	1	50
Young	Old	4	3	1	75
Adult	Old	2	2	0	100
Old	Old	3	3	0	100

TABLE 5—RESULTS: DONORS OF DIFFERENT AGES

Donors	Number	Success	Failure	Per Cent. Success
Young	15	11	4	73
Adult	18	15	3	83
Old	10	8	2	80

TABLE 6.—RESULTS: RECIPIENTS OF DIFFERENT AGES

Recipients	Number	Success	Failure	Per Cent. Success
Young	16	13	3	81
Adult	18	13	5	72
Old	9	8	1	80

transplants than the adult or old donors. The percentages of successful homogenous transplants from the three age groups, however, is not strikingly different. In Table 6 the experiments are grouped according to the ages of the recipients of the homogenous transplants independent of the ages of the donors. It will be noted that the adult recipients showed the smallest proportion of successful results. The difference is not great, but the number of experiments in each group is sufficiently large to be indicative of a possible age influence on homogenous transplantation of bone in dogs. It would seem, however, that the age influence was not the most important factor, and that

it was more often other factors of incompatibility of host and transplant which determined the success or failure of the transplant to survive and grow.

In transplantation of tissue two groups of factors always influence the transplants.

One group of factors has to do with the transplant and the other with the reaction of the bed into which it is placed. In autogenous transplantation of bone as carried out in these experiments in which the bone grafts were placed in a defect in the shaft of a bone, the external influences are certainly the most favorable for the survival and growth of the transplant, since the transplant is taken from the same individual and placed in a site in which bone is normally present and exercises its normal functions. It is, therefore, certainly reasonable to believe that with autogenous transplants placed in such favorable environments, the success or failure of the transplant would depend largely on the internal factors alone. The age of the animal is certainly an important factor in determining the relative regenerative powers of bone, and therefore in determining the regenerative powers of a transplant of bone.

In the homogenous transplantations of bone as carried out in these experiments the influences as regards "functional demand" were the same as in the autogenous transplants. The age influence on the power of regeneration of the transplants independent of their environment must be assumed to have been the same in both types of transplants. In the homogenous transplants the incompatibility of tissues of different individuals was a factor which was not present in the autogenous transplants. From the results obtained in these experiments it would seem that this factor was more important than the age factor in determining the success or failure of the transplant.

That the age of the donor must influence the intrinsic power of growth of a bone transplant would seem to be a conclusion unavoidable. Also the capacity of the recipient to react to the presence of a foreign tissue must vary with the age of the individual, probably being least in the very young and old, and greatest in the adult. The direct demonstration of the truth of these assertions is obviously impossible, as any experiment is an inseparable combination of donor and recipient, each with its many varying properties. The experiments described in this paper are incomplete in that very young and very old animals were not used. No experiments were carried out on animals which were related. Also the experimental method was such that only the results of the transplantations as regards actual new bone formation were observed. No study of the reactions of the beds of the transplants was made.

The experiments do show conclusively, however, that the influence of the age either of the donor or recipient was not of sufficient importance to manifest itself in a considerable number of experiments. The ages of the animals were of sufficient range and the experimental method was suitable to determine the practical application of homogenous bone transplantation.

Further experimental study of homogenous bone transplants as regards the reaction of the tissues of the host to the transplant in animals of varying age and relationship will be interesting. It would seem that bone would be a particularly suitable tissue for the study of homogenous transplantation, since it is less specialized and regenerates more readily than glandular tissue, and it is a tissue which is easily recognized by macroscopic, microscopic, and vital staining methods. It is possible that it could be determined by preliminary tests whether a homogenous bone transplant would succeed or fail. In a considerable number of the experiments described in this paper the red blood corpuscles and the blood serums of the animals were tested for the presence of iso-agglutinins and hemolysins. None were demonstrated by routine clinical methods. It should be borne in mind that blood transfusions and homogenous transplantations of tissue are not similar procedures, as in the former material which has no regenerative powers is transplanted while in the latter the host must do more than simply tolerate the alien tissue. It is probable that the success of homogenous transplantation of tissues is entirely independent of blood groups, since Loeb [10] has shown that relationship of animals has an important influence on the results of homogenous transplantation of tissue, and Happ [11] and others have shown that relationship has no influence on blood groups.

CONCLUSIONS

1. A defect in the shaft of a bone of a dog may be permanently regenerated by a bone transplant removed from another dog.

2. Homogenous transplants of bone were successful in 76.8 per cent. of instances as compared with 84.8 per cent. of successful results in autogenous transplants.

3. The age of the animals is an important factor in determining the proportion of success and failure of autogenous transplants of bone in dogs.

4. The importance of the age of the donor or recipient as a factor in determining the success or failure of the homogenous transplant of bone in a dog is probably of less importance than factors of incompatibility of tissue of different individuals.

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10. Loeb, L.: J. M. Res. **39**:39 (Sept.) 1918.
11. Happ, W. M.: J. Exper. Med. **31**:313 (March) 1920.

GALLBLADDER DISEASE

A STATISTICAL STUDY

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Next to appendicitis, gallbladder disease is probably the commonest intra-abdominal lesion. This is evidenced both by the reports of operative procedure and by necropsy statistics. Mitchell,[1] in 1918, reporting the gallstone incidence in 1,600 necropsies of all ages, gave a comprehensive report of 122,808 postmortems from American and European sources. Among them were 7,022 gallstone cases, or an average of 5.7 per cent. In 1914, Hesse[2] in a somewhat similar report found 4,848 gallstone cases, or 6 per cent. in 80,802 postmortems. The usual age at which the necropsy was performed in this latter series was 60-70 years. It is interesting to note that among these 4,848 cases in only 16 per cent there were symptoms referable to gallstones.

In accepting such figures one must consider (1) that they concern for the most part elderly people in whom cholelithiasis or gallbladder disease is more to be expected; (2) that they comprise mainly the working classes rather than the more well-to-do, well nourished class in whom gallbladder lesions are more common; (3) that they include those only in whom gallstones were taken as evidence of gallbladder disease; (4) that coming from pathologic reports from public institutions, the histories undoubtedly are rather incomplete; (5) that they consider the incidence of gallstone disease in those dying from all causes and do not represent the average sick case.

W. J. Mayo,[3] in 1,244 cases in which operation was performed for uterine myoma, found incidentally ninety-two cases, or 7.2 per cent. of gallstones, and Peterson[4] in Ann Arbor, reported 135 cases of gallstones, 12.5 per cent., in 1,056 cases which came to operation for definite gynecologic lesions. Naunyn in his original work remarks that about 10 per cent. of the human race have gallstones. W. J. Mayo thinks this rather high and conservatively remarks that about 0.5 per cent. would be more nearly the correct incidence.

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1. Mitchell, L. J.: Incidence of Calculi in the Gallbladder as Met with in 1,600 Necropsies, Ann. Surg. **68**:289 (Sept.) 1918.
2. Hesse, E. R.: Frequency of Gallstones, Russk. Vrach **13**:289, 1914.
3. Mayo, W. J.; Innocent Gallstones a Myth, J. A. M. A. **56**:1021 (April 8) 1911.
4. Peterson, Reuben: Gallstones During the Course of 1,066 Abdominal Sections for Pelvic Disease, Surg., Gynec. & Obst. **20**:284, 1915.

During the six years since the opening of the Peter Bent Brigham Hospital an increasing number of gallbladder cases have been admitted to the surgical service, in all 470, or 4.1 per cent., of the 11,622 surgical admissions. Of these, 397 came to operation, or 4.2 per cent., out of a total of 9,484 operations. A study of this series of gallbladder cases in a statistical manner forms the subject of this paper.

INCIDENCE OF GALLBLADDER DISEASE

Most writers on gallbladder disease have noted the great preponderance of the disease in the female sex as contrasted with the male. From necropsy reports, Mitchell found a ratio of 3 to 1, and Hesse, of 7 to 1. From operative statistics, Mayo,[3] in his series of 4,000 cases, found 3,075 female cases and 925 male. Hubbard and Kimpton,[5] in the Boston City Hospital series of 400 cases, reported a ratio of 3 to 1. Rhodes,[6] in 172 cases, found a ratio of 3 to 1. Deaver,[7] in his 1914 report, dividing gallbladder diseases into three classes, (1) simple

TABLE 1.—INCIDENCE OF GALLBLADDER DISEASE BY AGE AND SEX

Decade	Number of Cases			Percentage		
	Male	Female	Total	Male	Female	Total
0–10	0	0	0	0	0	0
11–20	2	3	5	0.5	0.8	1.3
21–30	5	43	48	1.26	10.8	12.0
31–40	21	78	99	5.3	19.7	25.0
41–50	24	82	106	6.0	20.6	26.6
51–60	18	79	97	4.5	20.0	24.5
61–70	9	27	36	2.3	6.8	9.1
71–80	3	3	6	0.75	0.75	1.5
Total	82	315	397	20.6	79.4	100.0

cholecystitis with or without stones; (2) cases with common duct involvement, and (3) cases with secondary pancreatic involvement, found a ratio of 5 to 1 in the first simple group, decreasing to 2.2 to 1 in the second and third groups. In the Brigham series of 397 cases, there were 315 female cases and eighty-two male cases, a ratio of 4 to 1. This preponderance has been ascribed to various conditions, among which may be noted (1) the sedentary habit of women; (2) the poor muscle tone with ptosis of abdominal walls and organs, causing kinking of the extrahepatic ducts; (3) the frequency of pelvic infection with blood stream extension; (4) the mechanical effect of the

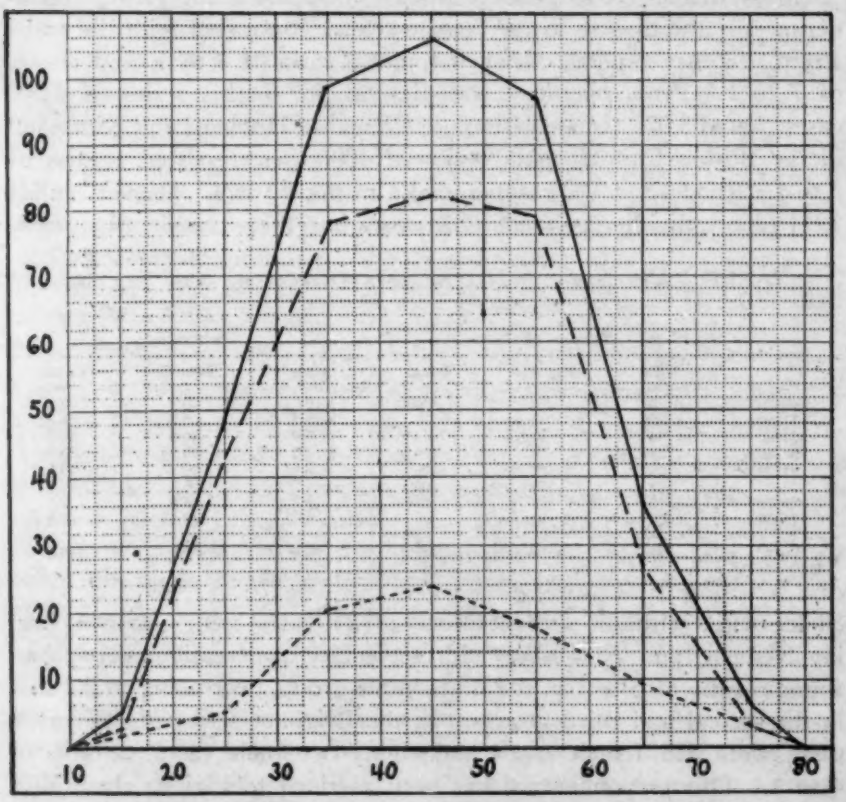
5. Hubbard, J. C., and Kimpton, A. R.: Gallstones, A Statistical Study of Cases Occurring at Boston City Hospital, Ann. Surg. **61**:535, 1915.

6. Rhodes, R. L.: Observation in 133 Cases of Gallbladder Surgery with Special Reference to Postoperative Treatment, Surg., Gynec. & Obst. **23**:399, 1916.

7. Deaver, J. B.: A Report of the Cases of Gallstone Diseases Operated on During the Year 1914, Ann. Surg. **62**:197, 1915.

enlargement of the uterus during pregnancy; (5) the supposed hypercholesterinemia, and (6) the concentration and inspissation of bile during pregnancy.

Gallbladder disease is essentially a disease of middle age. Undoubtedly many lesions originate early in life but remain dormant or produce indefinite minor or vague symptoms until middle age. It occurs with increasing incidence with the advancing decades, the greatest frequency being between 40 and 50 years of age. Table 1 gives the incidence



Curve of incidence: solid line, total; broken line, female; dotted line, male.

according to the decades of this series. It shows a total of 76.1 per cent. occurring between the ages 31 and 60, with the highest percentage (26.6 per cent.) occurring in the fifth decade. The accompanying chart shows the curve of incidence. Gallbladder disease is considered rare below 20 years of age. Mayo, in 4,000 cases, recorded forty-one under 20 years of age, three of them being males. Babcock,[8]

8. Babcock, W. W.: Cholecystectomy and Cholecystic Toxemia, J. A. M. A. 65:1428 (Oct. 23) 1915.

reported one of 14 and one of 4 years of age. Buchanan,[9] in 300 cases, described one of 5 and one of 19 years of age. Kimpton, in 400 cases, reported one of 16 years of age. In this series there were five below 19 years of age of which brief mention will be made.

REPORT OF CASES IN EARLY LIFE

CASE 1.—A schoolgirl, 19 years of age, with recurring attacks of sharp pain lasting from fifteen to twenty minutes in right lower abdomen, some nausea and vomiting, which were aggravated by eating, was referred to the hospital for appendicitis. Operation showed two large gallstones in the gallbladder, which was the seat of chronic cholecystitis. Cholecystectomy and appendectomy were performed. (S. 5128.)

CASE 2.—A schoolgirl, aged 14, complained of repeated attacks of jaundice when a young girl. During the preceding eleven months there were recurrent attacks of pain, mainly in the upper abdomen, radiating to the back and shoulder, but with no nausea or vomiting, and only slight jaundice. There was abdominal tenderness after these attacks. Operation showed old pericholecystic adhesions and a shrunken gallbladder with many stones. Cholecystectomy and appendectomy were performed. (S. 5515.)

CASE 3.—A schoolgirl, 17 years of age, gave a history of two attacks during the preceding three months of crampy, colicky, right lower abdominal pain with no nausea or vomiting; in the first attack there was radiation of pain to back and shoulder, fever and abdominal tenderness. Operative findings disclosed a normal pelvic appendix and a large distended gallbladder with four large stones. Cholecystostomy and appendectomy were performed. (S. 8215.)

CASE 4.—A boy, 17 years of age, was first admitted to the hospital with a history of severe crampy colicky pain, starting in the upper abdomen and later becoming diffuse. Occasionally the pain radiated to the right upper quadrant, there were marked nausea, vomiting and severe constipation. He was therefore referred to the hospital for intestinal obstruction. The findings were essentially negative except for a rise in temperature to 100 F. and a white blood cell count of 17,000, immediately becoming normal. Relief was obtained by enemas. German measles developed, and the patient was later discharged. Twenty-four hours after discharge, he reentered with very severe excruciating pain in the upper abdomen radiating to back and shoulder, and tenderness under the right costal margin. His temperature was 99 F., pulse rate 80, the white blood cell count 13,000. Operation showed an acute inflammatory gallbladder, thick-walled, with mural abscesses and gallstones. Cholecystectomy and appendectomy were performed. (S. 9183.)

CASE 5.—A schoolboy, 13 years of age, was referred to the hospital for upper abdominal pain, diffuse, with occasional acute exacerbations during the preceding six days. Examination revealed moderate tenderness in the upper abdomen, some jaundice, a temperature of 100.6 F., and a white blood cell count of 8,000. Operation showed a subacute cholecystitis, but no stones. Cholecystectomy was performed. (S. 9580.)

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9. Buchanan, J. J.: End-Result of a Series of 300 Operations on the Gallbladder, Surg., Gynec. & Obst. **21**:499, 1915.

One can infer from the incidence by decades that gallbladder disease is more frequent in the married than in the single woman. W. J. Mayo found that 90 per cent. of gallbladder diseases in the female occurred in married women, and that about 90 per cent. of these had borne children. Rhodes found 88.3 per cent. and Peterson 84 per cent. Deaver remarks that four fifths of all gallbladder cases occur in married women. In this series, 88.6 per cent. of all female cases were in married women, and of these 87 per cent. had passed through one or more pregnancies. There were only thirty-six single women among the 315 female cases. Table 2 shows the incidence by decades in married and unmarried women, and shows the relation of the increasing number of pregnancies to the frequency of gallbladder disease.

TABLE 2.—INCIDENCE OF GALLBLADDER DISEASE BY DECADES IN RELATION TO MARRIAGE AND PREGNANCY

Decade	Number of Cases			Percentage		Children		Percentage		Average No. of Children
	Total	Single	Married	Single	Married	Without	With	Without	With	
10-20	3	3	0	100.0	0	0	0	0	0	0
21-30	43	2	41	4.6	95.4	7	34	17.0	83.0	2.2
31-40	76	5	71	6.6	93.4	11	60	15.5	84.5	3.7
41-50	88	11	77	12.5	87.5	5	72	6.5	93.5	4.3
51-60	74	8	66	10.8	89.2	9	57	13.6	86.4	3.9
61-70	28	5	23	17.0	83.0	6	17	26.0	74.0	3.3
71-80	3	1	2	33.0	67.0	..	2	....	100.0	2.0
Total	315	35	280	....	....	38	242			

ETIOLOGY OF GALLSTONES

Galippe,[10] in 1886, was the first to advance the bacterial origin of lithiasis in general. To Gilbert,[11] however, belongs the credit for definitely demonstrating the infectious origin of cholelithiasis. His experiments, together with those of his associates, beginning in 1890, were largely responsible and formed the foundation of Naunyn's theory of bacterial origin of gallstones which the latter propounded at the Congress of Wiesbaden in 1891. Welch,[12] in 1890, had demonstrated the presence of *Bacillus coli* and *Staphylococcus pyogenes* in gallstones and suggested that they might be a nucleus for their for-

10. Galippe, V.: Mode de formation du tartre et des calcul salivaires, considérations sur la production des calculs en général, présence des microbes ou de leurs germes dans ces concrétions, Jour. des connaissances méd. (25 mars) 1886; Compt. rend. Soc. de biol., Series 8, 3:116, 1886.

11. Gilbert, A.: Note pour service à l'histoire de la théorie microbienne de la lithiase bilaire, Arch. gén. de méd. 2:257, 1898.

12. Welch, W. H., quoted by Moynihan, B. G. A.: Gallstones and Their Surgical Treatment, Ed. 2, Philadelphia, W. B. Saunders Company, 1905.

mation. Blachstein [13] and Welch,[14] in 1891, noted the constant occurrence of bacilli in the gallbladder in cases of animals experimentally inoculated with colon and typhoid organisms. In 1893, Gilbert and Dominici [15] noted several small concretions in the gallbladder in experimentally produced cholecystitis in rabbits and, in January, 1897, they produced definite gallstones in the gallbladder of dogs by inoculation of colon bacilli. In May, 1897, Mignot [16] produced stones in the gallbladder of guinea-pigs in a similar manner. Gilbert and Fournier [17] produced, in 1897, definite biliary calculi in rabbits, by the inoculation of typhoid bacilli. Mignot, after a long series of experiments, concluded that the chief elements in gallstone formation were (1) the presence of an attenuated organism of almost any variety, and (2) a stasis of the bile current to allow for the accumulation of precipitated material. Virulent organisms produced an acute cholecystitis and were not favorable for the production of gallstones. That gallstones could be produced experimentally has been verified by Cushing,[18] Richardson [19] and other investigators. The organisms producing them included *Bacillus coli, Bacillus typhosus, Staphylococcus pyogenes, Streptococcus pyogenes, Bacillus subtilis* and *pneumococcus*. Naunyn,[20] in putting forth the bacterial theory of gallstone formation, concluded that cholesterin was not a specific secretion from the liver but that the source of cholesterin in gallstone formation was from the degenerated, desquamated epithelial cells of the gallbladder wall and bile ducts, these changes being produced by a mild inflammation of bacterial origin, the so-called "lithogenous catarrh" of Naunyn. Aschoff and Bacmeister [21] showed that the glands of Luschka were in reality

13. Blachstein, A. G.: Intravenous Inoculation of Rabbits with Bacillus Coli Communis and the Bacillus Typhi Abdominalis, Johns Hopkins Hosp. Bull. **2**:96, 1891.

14. Welch, W. A.: Additional Note Concerning the Intravenous Inoculation of Bacillus Typhi Abdominalis, Johns Hopkins Hosp. Bull. **2**:121, 1891.

15. Gilbert and Dominici: Angiocholite et cholécystite typhiques expérimentales, Comptes rend. Soc. de biol. **5**:1033 (Dec. 23) 1893.

16. Mignot, quoted by Hartman, M. H.: Pathogenèse de la lithiase, Presse méd. **3**: (2 mars), 1898; L'origine microbienne des calculs biliaires, Arch. gén. de méd. **2**:129, 1898.

17. Gilbert and Fournier: Lithiase biliaire expérimentale, Comptes rend. Soc. de biol. 936 (Oct. 30) 1897.

18. Cushing, Harvey: Observation upon the Origin of Gallbladder Infection and upon the Experimental Formation of Gallstones, Johns Hopkins Hosp. Bull. **10**:166, 1899.

19. Richardson, M. W.: On the Rôle of Bacteria in the Formation of Gall-Stones, J. Boston Soc. Med. Sc. **3**:79, 1899.

20. Naunyn, Bernard: Die Gallensteinkrankheiten, Verhandl. d. Cong. f. inn. Med. **10**:17, 1891; compare, Naunyn, Bernard: A Treatise on Cholelithiasis, New Sydenham Soc. **158**: 1896.

21. Aschoff and Bacmeister: Die Cholelithiasis, Jena, 1909.

epithelial lined clefts or crypts in the gallbladder wall which under infection became greatly dilated, deepened and tortuous and filled with products of inflammation. Organisms surviving in the hidden passages of these clefts accounted for the reinfection of the gallbladder with reappearance of gallbladder symptoms. Cholesterin crystals and calculi could be seen in all stages of formation in these clefts. As a result of the infection, the bile salts were destroyed and the cholesterin, held in solution by virtue of biliary salts, was precipitated about the degenerated cells as a nucleus.

Rovsing [22] maintained that the chief cause of lithiasis was a concentration and inspissation of the bile during febrile states and pregnancy, calcium and, later on, bile salts being precipitated and forming a nucleus for the accumulation of cholesterin crystals. These facts were supported by the chemical analysis of the stones in their early state of formation and by the high percentage of cases in which the bile was found sterile on culture. He believes that the formation of stones always preceded the infection and that infection might subsequently follow from the irritation of the calculus as a foreign body.

Granting the infectious theory as the more plausible, there are three general routes of infection: (1) ascending infection from the duodenum to common and cystic ducts into the gallbladder; (2) descending infection through the portal system into the liver and through the bile ducts into the gallbladder, and (3) the vascular or hematogenous route. The first of these is highly improbable because of the almost continuous current of bile towards the duodenum and also on account of the great difficulty, from anatomic conditions, of producing an efflux from the duodenum into the gallbladder. The first two are also rather improbable because they presuppose infection from the mucous membrane side of the gallbladder. Mucous membrane, however, is well constructed for surface protection and very resistant to such infection. Rosenow [23] has given special emphasis to the hematogenous method. He believes that gallstones are one of the results of cholecystitis, that cholecystitis is caused by the bacterial invasion of the gallbladder wall, septic infarcts of the capillaries being found in the base of the mucous membrane which result in areas of necrosis, either local or general. He believes in the specificity of infecting or invading organisms—a selective localization of the infection. Organisms developing in a

22. Rovsing, T.: Studier over Galdestenenes Patogenese, Hospitalstidende **8**: 249, 1915.

23. Rosenow, E. C.: Bacteriology of Cholecystitis and Its Production by Injection of Streptococci, J. A. M. A. **63**:1835 (Nov. 21) 1914. The Etiology of Cholecystitis and Gallstones and Their Production by the Intravenous Injection of Bacteria, J. Infec. Dis. **19**:527, 1916.

special organ or tissue have their properties so modified by this special environment that when introduced into another host they select this special tissue or organ and produce their specific lesions in that definite area. By his special technic, he has been able to get in cases of cholelithiasis and cholecystititis, a high percentage of cultures from bile, gallbladder wall, calculi and the draining lymph glands, and has been able to reproduce the gallbladder lesions by introducing the organisms intravenously into animals. Deaver has noted the association of appendicitis with cholecystitis and infers that the appendix may act frequently as a primary focus of infection.

More recently Henes [24] has contended that, while infection may play a rôle in gallstone formation, while bacterial growth may alter the chemical composition of the bile, and while inflammation of the mucous membrane may produce epithelial desquamation for gallstone formation, after all a condition of hypercholesterinemia is the primary and fundamental etiologic factor in gallstone formation. A large number of gallbladders with stones, particularly the cholesterin stones, according to him, show no evidence of infection. He reports thirty-eight cases of cholelithiasis, all showing a definite hypercholesterinemia, and suggests the use of cholesterin determinations as a valuable diagnostic adjunct. He infers that such cases have a definite diathesis which may evidence itself in many ways, such as arteriosclerosis, gallstones, nephritis, etc. Aoyama's [25] experimental work in producing gallstones or concretions similar to gallstones by subcutaneous injection or by oral feeding of cholesterin or its esters appears to give some support to his views.

Galindez [26] still more recently disputes the value of cholesterin determination in gallbladder diagnosis. He has found no constant hypercholesterinemia, even in those cases in which the liver function has been seriously interfered with. In cases of catarrhal icterus he has found normal cholesterin content. In a large number of common lesions unrelated to gallbladder or liver functions, such as appendicitis and pulmonary tuberculosis, he has found various grades of hypocholesterinemia and hypercholesterinemia. Rothschild and Rosenthal [27] found a general hypercholesterinemia associated with cholelithiasis. Many cases of cholelithiasis with positive findings at operation

24. Henes, Edwin, Jr.: The Value of the Determination of the Cholesterin Content of the Blood in the Diagnosis of Cholelithiasis, J. A. M. A. **63**:146 (July 11) 1914; Surg., Gynec. & Obst. **23**:91, 1916.

25. Aoyama: Experimenteller Beitrag zur Frage der Cholelithiasis, Deutsch. Ztschr. f. Chir. **132**:234, 1914.

26. Galindez, A.: The Importance of Hypercholesterinemia in Biliary Calculus, An. d. Inst. Mod. de clin. med. **3**:225, 1919.

27. Rothschild, M. A., and Rosenthal, N.: Dietetic Management of Hypercholesterinemia, Am. J. M. Sc. **152**:394, 1916.

have had, however, a normal blood cholesterin content. These, they infer, undoubtedly had a previous hypercholesterinemia, but the precipitation of the cholesterin under infection and gallstone formation automatically reduced the blood cholesterin content to normal. They divided cholelithiasis into two groups, those with a normal cholesterin content and those with a hypercholesterinemia. The latter consisted of two groups. The first was the obstructive type due to stone, stricture and new growth. In these the cholesterin content became normal on removal of the obstruction. The second group was due to a definite diathesis in which the hypercholesterinemia remained permanent even after the removal of the obstruction, if any was present. This condition they considered an entity as definite as the gouty diathesis. Gallstones were merely one of the evidences of this condition.

In a very recent paper Rothschild and Felson [28] noted that in obstructive icterus due to stone, there was a very high hypercholesterinemia bearing a definite relation to the severity of the icterus. In conditions associated with hepatic lesions, however, the cholesterin content was usually normal or below normal, being entirely out of proportion to the icterus. They suggest that in the hepatic disease there is a selective retention of the bile pigment and as a consequence the cholesterin is not retained. This should furnish a means of differentiating icterus of gallbladder origin from that of liver origin. They suggest also that, in operative procedures, the bile passages should be drained long enough to have the cholesterin content of the blood return to normal.

In this series no attempt was made to study intensively the bacterial findings. In 397 cases a history of previous typhoid fever was obtained from only forty patients, or 9.5 per cent. The symptoms of gallbladder disease in these cases dated from six months to forty-nine years after typhoid infection. In those cases of simple cholelithiasis which were subjected to culture, the bile as a rule was sterile, while in the cases of acute cholecystitis and empyema of the gallbladder the organisms found were colon bacilli, streptococcus and staphylococcus. Cushing,[29] in his series of gallbladder cases at Johns Hopkins Hospital, reported 30 per cent. of cases giving a definite history of typhoid fever. Lichty and Zurhorst,[30] in 122 cases of cholelithiasis and fifty-four cases of cholecystitis, found 17.2 per cent. and 37 per cent., respectively, giving histories of previous typhoid infection. Rhodes, in 132 cases, reported that 49 per cent. of the men and 24 per cent. of the women

28. Rothschild, M. A., and Felson: The Cholesterol Content of the Blood in Various Hepatic Conditions, Arch. Int. Med. **24**:520, 1919.

29. Cushing, Harvey: Typhoidal Cholecystitis and Cholelithiasis, Bull. Johns Hopkins Hosp. **9**:91, 1898.

30. Lichty, A., and Zurhorst, E. W.: Concerning End-Results of Gallbladder and Duct Disease, J. A. M. A. **65**:482, (Aug. 7) 1915.

gave definite histories of previous typhoid fever. Between these extremes there are a large number of contributors giving various percentages. On the other hand, cholecystitis does not appear to be a common complication of typhoid fever. Lothrop [31] reports a series of 2,864 typhoid cases with only eighteen cholecystitis complications, or 0.6 per cent., and another series of 895 cases in which 1.3 per cent. were so complicated. In 2,000 cases of simple typhoid fever coming to necropsy in Munich, only five, or 0.2 per cent., showed a cholecystitis. There evidently is now a marked discrepancy between the gradually decreasing incidence of typhoid fever and the increasing incidence of gallbladder disease, so that the typhoid bacillus can hardly now be considered as the more probable etiologic factor. Organisms also have been reported found in the gallbladder and on the inside of calculi from thirty to forty years after typhoid infection. Such a long residence under such conditions most probably would cause a change in the inherent properties of the organism so as to render it unadaptable to or unrecognizable by the ordinary routine culture method. Rosenow, with his special technic, has been able to find a much higher percentage of cultures than has ever been reported before. He finds that streptococcus and the colon bacillus are the most common invaders. The body, through its many atria of infection, is continually becoming infected with organisms, and some of these under various altered conditions, pass by the barriers of resistance, find suitable mediums, grow and produce their disease. The streptococcus, being the most prevalent organism of infection, is probably the cause of the greater number of cholecystitis or gallbladder infections.

CLINICAL GROUPS

Patients presenting themselves to the clinic were easily divided according to symptomatology into the following groups:

Group 1: Typical biliary group. These gave a history of biliary colic evidently associated with the movement of the stone down the biliary passages. The cases were characterized by severe pain, usually localized in the epigastrium or right hypochondrium, sudden in onset and in cessation, radiating usually to the back and shoulder, usually accompanied by nausea and vomiting, most of them requiring morphin for relief. Recurrent attacks usually extended over a long period of time, were of increasing frequency and were associated occasionally with transient jaundice. There were seven cases in which the pain was all left-sided. This group of cases furnished as a rule no difficulty in diagnosis, and consisted of 195 cases or 54.6 per cent. of the total.

31. Lothrop, H. A.: Acute Cholecystitis Complicating Typhoid Fever, Ann. Surg. 62:152, 1915.

Group 2: Atypical biliary group. In this group there was no acute biliary colic. The symptoms were mainly dull aching pain in the upper right quadrant, with tenderness, fever, some nausea and vomiting. The pain was usually of several days' duration. Jaundice may or may not have been present. These attacks were in the main fairly typically inflammatory in character and in findings, were usually accompanied by a septic temperature curve and a fairly high white blood count. Gastric symptoms were not marked. The cases of intermittent jaundice suggestive of ball valve disease were also included in this group, which included sixty cases, or 16.8 per cent. of the total number.

Group 3: Gastric Group. This group comprised those giving mainly gastric symptoms. The attacks were characterized by epigastric distress or discomfort, a feeling of fulness after meals, relieved by belching of gas and sometimes by vomiting. Idiosyncrasies for various kinds of foods were quite prominent, giving the so-called "qualitative" food dyspepsia in contrast to the "quantitative" food dyspepsia of gastric ulcer. Many of these patients had been treated for years for gastric or duodenal ulcer without any special permanent relief. These cases required rather intensive study of the gastro-intestinal tract before a definite diagnosis was made. The gastric examinations were fairly negative. Forty-nine cases, or 13.7 per cent. of the total number, were included in this group.

Group 4: Biliary-Gastric Group. This group gave symptoms typical of Group 1 and Group 3, namely, that of biliary colic with recurring intervals of gastric symptoms. In some, the symptoms of colic were most prominent, in others the gastric symptoms. Fifty-three cases, or 14.8 per cent. of the total number, made up this group.

GASTRIC ANALYSIS

No special assistance in diagnosis was obtained from the analysis of the gastric contents in this series of cases. Lichty,[32] in 1911, and Lichty and Zurhorst,[30] in 1915, reported a hyperchlorhydria in from 50 to 73 per cent. of cholelithiasis and cholecystitis cases. The former, by experimentation in the dog, had demonstrated an apparent increase in the hydrochloric acid content of the gastric secretion after experimental cholecystitis and cholethithiasis. Hohlweg,[33] on the other hand,

32. Lichty, J. A.: Relation of Diseases of Gallbladder and Biliary Ducts to the Gastric Secretions, Am. J. M. Sc. **141**:72, 1911.

33. Hohlweg, H.: Disturbance in Hydrochloric Acid Secretion in Diseases of and Following Extirpation of Gallbladder, Am. J. M. Sc. **146**:292, 1913; Ueber Störungen der Salzäureabscheidung des Magens bei Erkrankungen und nach Extirpation der Gallenblase, Deutsch. Arch. f. klin. Med. **108**:255, 1912.

found a definite acid deficit or a hypo-acidity in cholelithiasis and particularly after removal of the gallbladder or on closure of the cystic duct. Bile itself seems to have no influence whatever on the gastric secretions, as is demonstrated by the experimental cholecystogastroenterostomy of Grey.[34] Regurgitation of duodenal contents with the bile, of course, lowers the acidity of the gastric contents through addition of the alkaline duodenal fluid. In this series of gallbladder cases, fractional analyses of the gastric secretion were made in seventy-five cases; 82.7 per cent. of these were within the limits of normal acidity, 13.3 per cent. showed hypo-acidity or anacidity, while only 4 per cent. showed a hyperacidity. No special difference was found in the cholelithiasis cases in contrast to the cholecystitis cases.

Meltzer,[35] in 1917, observed that duodenal instillation of magnesium sulphate was followed by relaxation of the sphincter of Oddi and a contraction of the gallbladder, there being a general outpouring of bile into the duodenum. Lyons,[36] in 1919, made a clinical application of this fact and by a duodenal tube was able to obtain fractional samples of bile representing that from (1) the common duct, (2) stored-up bile from the gallbladder and (3) that secreted by the liver itself. This undoubtedly opens up a new avenue of investigation concerning the bile and its secretion.

ROENTGENOLOGIC DIAGNOSES

Regarding the usefulness of the roentgenologic diagnosis in gallbladder disease there seems to be a diversity of opinion. Various roentgenologists using practically the same technic report positive findings of calculi in from 5 to 90 per cent. of cases. The difficulty, of course, is due to the lack of shadow cast by the cholesterin salt calculus. George and Cole[37] have perfected their technic so that now they believe all stones should be shown in the roentgenograms. The former[38] reports a series of fifty-four cases with only 10 per cent. of error in the positive findings, and 6 per cent. of error for the whole series. The majority of roentgenologists, however, have not been so

34. Grey, E. S.: An Experimental Study of the Effect of Cholecystgastrostomy on Gastric Acidity, J. Exper. Med. **23**:15, 1916.

35. Meltzer, S. J.: The Disturbance of the Law of Contrary Innervation as a Pathogenic Factor in the Diseases of the Bile Ducts and Gall Bladder, Am. J. M. Sc. **153**:469, 1917.

36. Lyons, B. B. V.: Diagnosis and Treatment of Diseases of the Gallbladder and Biliary Tract, J. A. M. A. **73**:980 (Sept. 27) 1919.

37. George, A. W., and Cole, L. G.: The Roentgen Diagnosis of Gallstones by Improved Means, Boston M. & S. J. **172**:326, 1915.

38. George, A. W.: Some Further Notes on the Roentgen Diagnosis of Gallstones, Interstate M. J., Suppl. Roentg. **2**:13, 1916.

fortunate thus far in attaining such efficiency. Speed, small focal areas, the taking of many plates and the superposition of plates have helped to increase the efficiency of roentgen-ray diagnosis in gallbladder diseases.

Mayo says that to put too much dependence on the roentgenologic diagnosis of gallstones would be a backward step of many years. Deaver considers it dangerous; first, because it fails to show the stone in the largest number of cases and, second, because it emphasizes the calculus feature. He considers the gallstones as only one of the terminal stages and by no means a uniform accompaniment or the most dangerous feature of the condition. In the series reported here, a positive diagnosis of gallstones was made by roentgen ray in forty-four out of 160 cases, or 27.5 per cent., the findings being confirmed by operation.

OPERATIVE PROCEDURES

Table 3 gives the operative procedure and operative findings of these 397 cases.

COMMON DUCT COMPLICATIONS

Oddi,[39] in 1887, discovered a sphincter of plain muscle surrounding the duodenal end of the common duct at the ampulla of Vater. It was composed of circular muscle fibers and could be put into spasm by irritation, mechanical or chemical, from the duodenal side. It was able to withstand an interductal pressure of 675 mm. of water. Sphincter action caused an intermittent flow into the duodenum of the bile continuously secreted by the liver and served to maintain a definite pressure in the hepatic duct system. Oddi also observed the dilatation of the extrahepatic ducts in dogs following removal of gallbladder. Archibald,[40] in 1912-1913, verified the action of the sphincter in maintaining an interductal pressure and showed that incision of the sphincter caused a reduction of the high interductal pressure from 650 to 70 mm. of water. This low pressure was maintained for a long time if not permanently. He also proved that pancreatitis could be produced by flooding the pancreas with bile and other substances through the common duct maintained at a pressure above the normal pressure allowed by sphincter action, and suggested cutting the sphincter as one of the surgical procedures in the treatment of this condition. Judd and

39. Oddi, R.: Di una speciale disposizione di sfintere allo sbocco del coledoco, Perugia, 1887, quoted by Luciani, L.: Human Physiology **2**:214, 1913.

40. Archibald, E.: A New Factor in the Causation of Pancreatitis, Tr. Int. Cong. Med., Surg. Sect. **7**:21, Part 2, 1913; The Experimental Production of Pancreatitis in Animals as the Result of the Resistance of the Common Duct Sphincter, Surg., Gynec. & Obst. **38**:529 (June) 1919.

Mann,[41] by extirpation of the gallbladder in dogs, demonstrated the great dilatation of the extrahepatic ducts. Following the operation, the sphincter was evidently in a condition of contraction attempting to maintain the normal interductal pressure. The ducts as a consequence dilate and the sphincter under the continued pressure tension becomes paralyzed with final reduction of the interductal pressure. Eisendrath [42] and Haberer [43] report cases in which they found dilatation of the extrahepatic ducts after cholecystectomy and also cases

TABLE 3.—Operative Results in Cases of Gallbladder Disease

	Cholecystostomy	Cholecystostomy, Choledochostomy	Cholecystectomy	Cholecystectomy, Choledochostomy	Choledochostomy	Cholecystenterostomy	Repair of Bile Ducts	Exploratory Laparotomy
Cholecystitis:								
A. Calculous (315)								
1. Acute	6	1	16	10	1	..	1	..
2. Subacute	0	0	16	6	0	..	..	..
3. Gangrenous	1	0	10	0	0	..	..	..
4. Empyema	0	0	7	1	0	..	..	..
5. Chronic	8	2	134	90	6	..	2	..
B. Noncalculous (50)								
1. Acute	0	0	3	0	1	..	..	..
2. Subacute	0	0	0	0	0	..	..	..
3. Gangrenous	0	0	2	0	0	..	..	..
4. Empyema	0	0	2	0	0	..	..	..
5. Chronic	1	1	19	5	0	..	..	..
6. Normal	0	0	16	0	0	..	..	..
Pancreatitis (14)								
Acute: (7)								
1. With acute cholecystitis	3	1	..	..	..	..	..	..
2. With chronic cholecystitis	3	..	..	..	..	..	..	..
Chronic: (7)								
1. With acute cholecystitis	..	..	..	1	..	..	..	..
2. With chronic cholecystitis	1	..	..	5	..	..	..	..
Cholelithiasis: Calculus in								
1. Gallbladder (244)	20	1	184	39	..	..	..	..
2. Common duct (11)	..	3	..	..	8	..	..	..
3. Gallbladder and common duct (78)	..	4	..	74	..	..	..	..
4. Cystic duct (7)	..	..	7	..	..	..	..	..
Neoplasms: Carcinoma (18)								
1. Gallbladder (6)	..	..	..	..	1	..	..	5
2. Bile ducts (1)	..	..	..	..	1	..	..	..
3. Head of pancreas (11)	2	..	..	..	..	5	..	4

in which a gallbladder-like structure was formed out of the incompletely removed cystic duct. Deaver,[44] however, in his 1,800 cases of

41. Judd, E. S., and Mann, F. C.: The Effect of Removal of the Gallbladder, An Experimental Study, Surg., Gynec. & Obst. **24**:437, 1917.

42. Eisendrath, D. N., and Dunlavy, H. C.: The Fate of the Cystic Duct after Cholecystectomy, An Experimental Study, Surg., Gynec. & Obst. **26**:110, 1918.

43. Haberer and Clairmont: Experimentelle Untersuchungen über das Verhalten des Cysticusstumpfes nach Cholecystectomie, Arch. f. klin. Chir. **73**:679, 1904.

44. Deaver, J. B.: Cholecystostomy vs. Cholecystectomy, Surg., Gynec. & Obst. **24**:284, 1917.

gallbladder operations, has not found a single case in which there was any marked dilatation of the ducts following cholecystectomy. From the experimental side, it seems probable that a dilatation of the ducts may follow a cholecystectomy.

Just what constitutes a dilated common duct, in view of the many abnormalities of the gallbladder and biliary passages, it is difficult to say. In the 397 cases reported here, the common duct, in 113 cases, was of such size as to indicate, in the operator's opinion, exploration. In seventy-six cases stone was found in the common or hepatic duct, and no stone in thirty-seven cases. There were also four cases in which the common duct appeared to be normal in size but which contained small stones. In this series a small contracted gallbladder, usually a "nubbin" of a gallbladder, contracted on stones, was found sixty-one times. This gallbladder, usually a mass of fibrous tissue, hard and firm, without any definite lumen, is certainly a nonfunctioning gallbladder and has been produced by a long series of inflammatory insults with or without stone formation. So far as function is concerned, it represents a slow cholecystectomy or progressive obliteration of the gallbladder. With this small contracted functionless gallbladder there was associated a large dilated common duct in thirty-seven cases. Twenty-five of these had stones in the common duct which could no doubt account for the dilatation. In twelve cases there was a large dilated common duct but no stones. On the other hand, however, a small contracted gallbladder was found in conjunction with a small normal common duct twenty-four times.

TABLE 4.—Common Duct Findings

	Number of Cases
Small, contracted, fibrous gallbladder	61
A. Large dilated common duct	37
(a) With stone	25
(b) Without stone	12
B. Small, normal, common duct	24

Under normal conditions the gallbladder undoubtedly readily compensates for the usual fluctuations of interductal pressure. After cholecystectomy the tension, if any, is suddenly put on the ducts, and they dilate in the least resistant portion—at or above the junction of the hepatic and common ducts. In slow obliteration of the gallbladder, as is seen in chronic cholecystitis with fibrosis, the ducts slowly accommodate themselves to the gradual increase in the duct pressure by hypertrophy of the walls, by adhesions and by increase in fibrous tissue. In these latter cases also the intrahepatic dilatation is likely to be more pronounced than that occurring after cholecystectomy.

GANGRENE AND EMPYEMA

Gangrene of the gallbladder is a fairly frequent occurrence. It is usually associated with stone impacted in the cystic duct or in a contracted gallbladder. The stone, as the fecolith in acute appendicitis, forms a pressure ulcer, eroding easily its way through the thickened, edematous gallbladder wall, devascularized usually by the mechanical obstruction to the blood supply produced by the calculus. Such gangrene associated with stone occurred in this series ten times, or in 2.5 per cent. of cases. Gangrene without calculus is rather rare. Kocher,[45] Korte,[46] Brunning [47] and Ransohoff [48] report cases in detail which on operation showed gangrene of the gallbladder without stone. The gallbladder itself is fairly resistant to gangrenous degeneration, having great powers of recuperation, and most of these patients were operated on from the eighth to the twelfth day. These were undoubtedly due to some severe virulent infection which caused inflammatory obstruction of the cystic duct with secondary interference of the blood supply. Ransohoff suggests that the S-shaped course of the cystic duct may account for the latter feature. With increasing distention, there would be sharper angulation of the cystic duct with its accompanying cystic artery, causing more complete obstruction not only to the cystic duct, but to the artery itself. Gangrene of the gallbladder without stones occurred in this series in two cases. Empyema, in a similar way, is usually caused by obstruction to the cystic duct, either by a stone impacted there or in the ampulla of the gallbladder, forming first a hydrops and then, by infection, an empyema. Such a condition occurred in thirteen cases in this series. Two of these empyemas were unassociated with calculus and were entirely inflammatory.

PERFORATION OF THE GALLBLADDER

Perforation of the gallbladder was found in six cases. Three of these were perforations into the duodenum without any acute peritoneal symptoms when admitted. On operation, they showed the usual mass of hard, fibrous tissue between the gallbladder and duodenum, suggestive of a gallbladder duodenal fistula. One was of more recent formation and was accompanied by a large colon bacillus abscess, subhepatic on the posterior abdominal wall. In all these cases

45. Kocher, Theodor: Ueber 100 Operationen an den Gallenwegen mit Berücksichtigung der Dauererfolge, Arch. f. klin. Chir. **81**:655, 1906.

46. Korte: Weitere Erfahrungen über Operationen an den Gallenwegen, Arch. f. klin. Chir. **89**:1, 1909.

47. Brunning: Cholecystitis acutissima haemorrhagica, Deutsch. Ztschr. f. Chir. **103**:407, 1909.

48. Ransohoff, J. L.: Acute Gangrene of Gallbladder Following Injury, Ann. Surg. **62**:420, 1915.

the fistula into the duodenum was closed and cholecystectomy was performed. There was one case of multiple perforations of a huge gangrenous gallbladder with general peritonitis, a terminal condition, the patient succumbing in two hours after abdominal drainage.

NORMAL GALLBLADDER

A normal gallbladder was removed in sixteen cases. This diagnosis was made on the microscopic examination, considering round cell infiltration, the presence of inflammatory cells as eosinophils and some increase in the fibrous tissue of the walls as indicative of a diseased gallbladder. These sixteen cases were unassociated with calculus. They must be considered definitely as wrong diagnoses. They were for the most part patients with vague gastric symptoms, with suggestive gallbladder findings on roentgen-ray examination. Error in diagnosis is also substantiated by the follow-up record of these cases, five out of seven patients reporting themselves as unimproved or in worse condition than before operation.

RECURRENCES AND SECONDARY OPERATIONS

Recurrences following gallbladder operation and requiring secondary surgical interference are fairly frequent, depending largely on the operator and the variety of the lesion. Judd,[49] of the Mayo Clinic, in 1918, reported 219 cases out of a total of 2,027, or 10.8 per cent. Sixty-four of these cases had the primary and secondary operation at that clinic. Deaver,[44] reporting 1,189 cases, had fifty-one secondary operations, or 4.2 per cent., 60 per cent. of these coming to operation in the first year, 90 per cent. within three years, and the remainder from four to seventeen years after the primary operation. Stanton [50] reporting the experience of six operators with a total of 1,173 cases, found recurrences in from 2 to 10 per cent. of cases treated by the various operators. Recurrences are classified as true or false, the former including those of evident reformation of calculus in the gallbladder and bile ducts. Naturally, they are found mainly in those cases in which a primary cholecystostomy was performed. The false recurrences include (1) stones overlooked at the first operation, (2) a persistence of the primary infection, (3) adhesions incidental to operation and (4) chronic pancreatitis. The work of Aschoff and Bacmeister,[21] confirmed by Ehrhardt,[51] has shown calculi reforming in

49. Judd, E. S.: The Recurrence of Symptoms Following Operation on the Biliary Tract, Ann. Surg. **67**:472, 1918.

50. Stanton, E.: Reformation of Gallstones after Operation, Ann. Surg. **61**:226, 1915.

51. Ehrhardt: Beiträge zur pathologischen Anatomie und Klinik des Gallensteinleidens, Arch. f. klin. Chir. **83**:1118, 1907.

the depths of Luschka's crypts or glands, which have been extruded to serve as the focus for reformation of stones. With the infected gallbladder remaining, stones may and will be found to recur after cholecystostomy. There seems to be no doubt that calculi can increase greatly in size while in the extrahepatic ducts, and cases have been reported in the literature of evident formation of calculi in the common duct, but it is extremely difficult to rule out the probability of stones overlooked at the previous operation. It seems rather strange that surgical reports do not contain more evidence of the intrahepatic formation of calculi, as such conditions have been found fairly frequently in postmortems. Beer,[52] in 1904, dissected 250 livers of patients who succumbed to gallbladder disease and found six cases of definite intrahepatic stone formation, or in 2.5 per cent. Lewisohn,[53] in 1916, reported a case of intrahepatic stone formation, there being several stones in the liver passages and one rupturing through the surface of the liver, forming a peritonitis. Hawkes [54] had previously reported a similar case, and Lenhartz,[55] in 1903, described a case in which the large and small intrahepatic ducts were filled with many calculi in various stages of formation, while the gallbladder was entirely devoid of the same. These appear to be the only cases of intrahepatic calculi in surgical literature. The stones seemed to be of different form, structure and character than those formed in the gallbladder, and according to the previously named authors are fairly well recognized. By far, however, the greatest number of occurrences are due to overlooked stones. Kehr,[56] in reporting 1,105 cases between the years 1890 and 1909, admitted overlooking calculi in 2.5 per cent. of cases. McWilliam [57] reported seven in sixty-nine cases at the Presbyterian Hospital in New York, and Whittemore [58] reported thirty secondary operations for similar cause in 325 cholecystectomies in the Massachusetts General Hospital. Kehr [59] explored forty-six common ducts in

52. Beer, E.: Intrahepatische Cholelithiasis, Arch. f. klin. Chir. **74**:115, 1904.

53. Lewisohn, R.: Intrahepatic Cholelithiasis, Ann. Surg. **63**:535, 1916.

54. Hawkes, F.: A Case of Intrahepatic Calculi; Removal; Drainage, Rep. Presbyterian Hosp. **7**:230, 1906.

55. Lenhartz, Hermann: Die septischen Erkrankungen, Nothnagel's Handbuch (Spezielle Pathologie und Therapie), 1903, p. 363.

56. Kehr, H.: Wie können wir Residive nach Gallensteinoperationen vermeiden und einschränken? München. med. Wchnschr. **58**:2425, 1911.

57. MacWilliam, C. A.: Critical Analysis of 186 Operations on the Liver and Gall Passages and the After-Results, New York M. J. **83**:1109, 1175, 1238, 1906.

58. Whittemore, W.: Surgery of the Biliary Passages During a Period of Ten Years, June, 1901, to June, 1911, at Massachusetts General Hospital, Boston M. & S. J. **169**:571, 1913.

59. Kehr, H.: Wann soll man nach einer Ektomie bei negativem Palpationsbefund von Steinen im Choledochus diesen Gang incidieren und drainieren und wann nicht? Arch. f. klin. Chir. **97**:301, 1912.

which palpation was entirely negative, and found calculi in seventeen cases in the retroduodenal portion of the common duct. Eisendrath,[60] in a similar way, found ten cases of calculi in the common duct in thirty cases in which external evidence and palpation failed to demonstrate the presence of the stone. Palpation of the supraduodenal portion of the common duct is fairly readily accomplished, but stones in the stagnant bile in the retroduodenal portion of the common duct just above the ampulla of Vater are very easily overlooked.

TABLE 5.—Recurrences and Secondary Operations

				Cases
Secondary Operation:				
A. Choledochostomy for common duct stone				8
Primary Operation:				
Cholecystectomy for stone			2 cases	
Choledochostomy for stone			1 case	
Cholecystectomy, Choledochostomy for stone			5 cases	
B. Cholecystectomy for stone				6
Cholecystostomy for stone			6 cases	
C. Cholecystectomy; cholecystitis; no stone				6
Cholecystostomy for stone			6 cases	
D. Cholecystectomy, choledochostomy for stone				6
Cholecystostomy for stone			6 cases	
E. Exploratory laparotomy for malignancy				2
Cholecystectomy for supposed chronic cholecystitis and pancreatitis			2 cases	
F. Repair of injured bile ducts				2
Among these 30 cases requiring secondary operations there were 16 which had the primary and secondary operations in this hospital:				
A. Primary cholecystostomy for stones in the gallbladder				6
B. Injury to bile ducts requiring secondary operation (1 fatality)				3
C. Secondary laparotomy for malignancy of biliary tract; primary operation being for chronic cholecystitis and pancreatitis; error in diagnosis				2
D. Cases of definitely overlooked stone in bile ducts				5
	Primary Operation	Secondary Operation	Tertiary Operation	
1.	Cholecystectomy	Choledochostomy	Choledochostomy	
2.	Cholecystectomy choledochostomy	Choledochostomy		
3.	Cholecystectomy	Choledochostomy		
4.	Cholecystostomy	Cholecystectomy choledochostomy	Choledochostomy	
5.	Cholecystectomy choledochostomy	Choledochostomy (fatality)		

In this series of 397 cases, confirmed by operation, there were thirty cases of recurrences or persistence of symptoms requiring secondary operation, a total series percentage of 7.5. Of these thirty cases, in sixteen cases the primary and secondary operations were performed in this clinic. This gives a percentage of 4.2 for secondary operation for the hospital series. This is a fairly low percentage and is due most probably to the fact that except for the earlier cases—accounting for six recurrences—cholecystectomy has been the operation of choice whenever feasible. Lund[61] quotes from statistics of a number of experienced operators, such as Mayo, Finney, and others, a symptomatic cure following cholecystostomy in about 75

60. Eisendrath, D. N.: Recurrences after Operations on Biliary Passages, J. A. M. A. **69**:1752 (Nov. 24) 1919.

61. Lund, F. B.: The Indications for Cholecystectomy, Surg., Gynec. & Obst. **24**:275, 1917.

per cent. of cases, 25 per cent. of patients operated on having somewhat similar symptoms. Out of twenty-six recurrences directly associated with cholelithiasis and cholecystitis, twenty had stones removed at the second operation, stones evidently having reformed or having been overlooked at the first operation; six were cases of cholecystitis without stones. Of the sixteen recurrent cases from this clinic, six were recurrences from former cholecystostomy, three of which had stones and three of which were cholecystitis. There were two cases which evidently were due to error in diagnosis, chronic pancreatitis being diagnosed at the primary operation and malignancy of the pancreas at the second. Three secondary operations were for injury to the bile ducts, and five were for definitely overlooked stones. It is regrettable that one of the patients with injury to bile ducts and one with overlooked stone succumbed after the secondary operation.

This does not include nine cases in which there had been previous operations for similar symptoms with no relief, evidently mistaken diagnosis. These comprise eight cases of appendectomy without relief of symptoms and one exploratory laparotomy with negative findings. These operations were all performed in other clinics. These nine patients had rather vague symptoms, mainly of gastric or duodenal character and gave some suggestive evidence, on roentgen-ray examination, of gallstone disease. In seven of the nine cases there was found definite cholecystitis or cholelithiasis or gastric or duodenal ulcers; in two there was a normal gallbladder.

INJURY TO BILIARY DUCTS

There are recorded in this series five cases of operative injury to the common duct, all of which occurred in this clinic. Two of these were repaired at the primary operation and three required secondary operation. These were in reality surgical errors due (1) to the difficulty of recognizing landmarks on account of the large mass of fibrous adhesions surrounding the ducts, and (2) failure to recognize some of the abnormalities of the biliary ducts and blood vessels which occur so frequently and have been noted in detail by Eisendrath.[62] Two of these divided common ducts were resutured and three were repaired over a rubber tube, one of which was removed at a secondary operation. The other two retained their tubes in the common ducts, as shown by the roentgen-ray sixteen and twelve months after the operation. These patients are perfectly well and have no discomfort whatever. One of these five patients with injury to the common duct succumbed after the second operation.

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62. Eisendrath, D. N.: Anomalies of the Bile Ducts and Blood Vessels, J. A. M. A. **71**:864 (Sept. 14) 1918.

PANCREATITIS

There undoubtedly is in the majority of cases a close association between primary infective diseases of the gallbladder and a complicating pancreatitis. Among the several etiologic factors of the latter disease there have been mentioned the retrojection of bile into the pancreas by obstruction at the ampulla of Vater and the extension of biliary sepsis either as an ascending infection to the pancreas or by way of the retroperitoneal lymphatics. Linder [63] found 50 per cent. of pancreatitis cases depending on or subsequent to cholecystitis and cholelithiasis. May reports that 85 per cent. of all pancreatitis cases are associated with gallstones and that 25 per cent. of them have common duct stones. He also remarks that 7 per cent. of all cases with gallstones in the gallbladder are associated with pancreatitis in some form, indicating that pancreatitis is four times as frequent with common duct stone.

In the series reported in this paper, acute and chronic pancreatitis was encountered fourteen times, as may be seen in Table 6.

TABLE 6.—Occurrence of Acute and of Chronic Pancreatitis

			No. of Cases
Acute Pancreatitis:			
(a) Hemorrhagic type. This is the fulminating type with hemorrhagic blood clot pancreas, blood stained abdominal fluid, fat necrosis, extreme toxemia			5
Associated with acute cholecystitis		3 cases	
Associated with chronic cholecystitis		2 cases	
Calculous in all cases—			
Common duct obstruction; stone in ampulla	1 case		
Common duct obstruction; swollen pancreas	1 case		
(b) Acute gangrenous pancreatitis; partial destruction of head of pancreas with abscess formation; fat necroses			3
Associated with acute cholecystitis		3 cases	
Calculous in all cases—			
Common duct obstruction; stone in ampulla	1 case		
Abscess in head of pancreas	2 cases		
(c) Subacute pancreatitis, swollen soft pancreas; frequent fat necroses; associated with acute cholecystitis			2
Chronic Pancreatitis:			
This is the large, hard, firm, indurated pancreas suggestive of malignancy on palpation, often times producing obstruction to the lower portion of the common duct			4
Associated with acute cholecystitis		1 case	
Associated with chronic cholecystitis		3 cases	
Calculus in gallbladder	4 cases		
Obstruction to common duct by enlarged pancreas	1 case		

All of these cases were associated with acute or chronic cholecystitis, usually of long duration, and all gave a history of biliary colic. Calculi were found in all but two of the cases, and there were two cases of definite obstruction at the ampulla of Vater by stone. In the acute cases of hemorrhagic type the patients were extremely ill, all of them succumbing in several hours after admission; two of them were practically moribund and did not survive attempted laparotomy. Drainage

63. Linder, William: Diagnosis of Acute Pancreatitis, J. A. M. A. **69**:718 (Sept. 1) 1917.

of the pancreas was the primary operation, with accessory drainage of the gallbladder if the patient's condition allowed. All of the patients with chronic pancreatitis did well. Cholecystectomy and choledochostomy with long continued drainage of the common duct was the operation of choice.

NEOPLASMS

Neoplasms of the gallbladder and biliary passages occurred in eighteen cases, or 4.5 per cent. of cases. Nine of these were entirely inoperable, nothing further being attempted beyond the exploratory laparotomy. Five cases were relieved by a cholecystenterostomy. Carcinoma of the gallbladder itself was encountered six times, five of them allowing of no operation on the gallbladder and one permitting a palliative choledochostomy. Carcinoma of the bile passages was very rare. In this series there was one case, namely, carcinoma of the hepatic duct above its junction with the common duct. There was complete obstruction, the common duct and gallbladder having no bile but a thick mucous fluid such as found in the ordinary hydrops of the gallbladder. Carcinoma of the head of the pancreas producing biliary obstruction occurred nine times, five of which permitted cholecystenterostomy, with relief for a period of thirteen months in the longest case. Most of these patients were deeply jaundiced, and there was a distressing oozing of blood in three of them following operation. In two, bleeding persisted for about three days and in the other for four days, the latter case ending fatally. As far as preventing persistent oozing, these patients did not react well to administration of blood serum or calcium lactate feeding by mouth. Whipple [64] has reported excellent results by intravenous infusions of 0.2 per cent. calcium lactate solution in amounts of 200 to 500 c.c. When this was given preoperatively to the intensely jaundiced patients there was very little bleeding. If given after the oozing started, the hemorrhage invariably stopped. He considered this treatment far superior in results to either administration of serum or blood transfusion.

CHOLECYSTOSTOMY VERSUS CHOLECYSTECTOMY

In this series of 397 gallbladder operations, cholecystostomy was performed sixteen times in contrast to 225 of cholecystectomy. In general, there has been a gradual decrease in the sphere of usefulness of the former operation. In the earlier cases of this series cholecystostomy was used in this clinic as the operation of choice. Owing, however, to recurrences both of cholelithiasis and cholecystitis, it has been reserved in this clinic for those acute cases in which the patient's

64. Whipple, A. O.: History Analysis Applied to Surgical Diseases of the Biliary Tract and the Pancreas, Ann. Surg. **68**:471, 1918.

condition contraindicated cholecystectomy or those few cases in which the gallbladder is necessary for cholecystenterostomy. Deaver [44] has estimated that 65 per cent. of his recurrences could have been obviated by removal of the gallbladder. Infection of the gallbladder wall is the essential factor in gallbladder disease with calculus formation as an accessory product of inflammation in about 75 per cent. of cases. The persistence of this chronic infection, with or without stone formation, is the cause of most of the subsequent recurrences, complications and the lowered percentage of symptomatic cures following cholecystostomy. It is also closely associated with the subsequent metabolic degenerative and organic changes in the body which increase the mortality rate in those cases subject to long-standing biliary infection. So far as can be ascertained, cholecystectomy has no special detrimental effect on the body economy. Patients observed by Mayo postoperatively for fifteen years have shown no special discomfort or disability. With the improvement in bacterial technic and with special means of diagnosis one wonders if a gallbladder, once the seat of infection, ever really becomes a normal functioning gallbladder or one free from infection. The recurrences following cholecystostomy are usually inflammatory and of a character similar to the primary infection. Those following cholecystectomy are usually mechanical and can be obviated by further care in the operative procedure. The mortality of the two operations is not essentially different in the simple cases. Deaver remarks that the mortality difference is as nothing compared to the local disease and general condition of the patient. In this clinic it has been the practice to consider cholecystectomy the operation of choice in all acute and chronic gallbladder infections when not contraindicated by the patient's condition. Cholecystostomy has been reserved for the acute critical suppurative cases or where a cholecystenterostomy was demanded.

FATALITIES

The deaths in this series numbered twenty-six, including all cases. According to operation, they are given in Table 7.

The mortality for the whole series of 397 cases was 6.5 per cent. Deducting the four terminal cases in which the patient succumbed on attempted laparotomy—moribund cases—gives a mortality of 5.5 per cent., divided as follows.

1. Acute and chronic gallbladder lesions requiring cholecystectomy—five deaths out of 224 cases, or 2.7 per cent.

2. Acute and chronic cases with common duct involvement requiring exploration of the common duct—twelve deaths in 126 cases, or 9.5 per cent.

3. Pancreatitis, acute and chronic, requiring drainage of pancreas, cholecystostomy, cholecystectomy or choledochostomy—five deaths in fourteen cases, or 36 per cent.

There is thus seen a gradual increase in the mortality rate with the increasing complication in the disease itself. This strongly argues for the early recognition and early operation in gallbladder disease.

TABLE 7.—DEATHS

	Time	Cause
Cholecystectomy:		
1. Chronic cholecystitis and cholelithiasis	Sudden; 11 hrs.	Unknown
2. Chronic cholecystitis and cholelithiasis	40 hours	Postoperative pneumonia
3. Chronic cholecystitis and cholelithiasis	36 hours	Postoperative pneumonia ?
4. Chronic cholecystitis and polyps	Sudden; 8 hrs.	Cardiac decompensation
5. Chronic cholecystitis and chronic hepatitis	Sudden; 1½ hrs.	Portal stasis
6. Chronic cholecystitis and cholelithiasis	Sudden; 12th day	Unknown
Cholecystectomy and Choledochostomy:		
1. Chronic cholecystitis and cholelithiasis	3 days	Acute gastric dilatation
2. Chronic cholecystitis and cholelithiasis	4th day	Postoperative pneumonia
3. Acute cholecystitis and cholelithiasis	18th day	Septic cholangitis
4. Chronic cholecystitis and cholelithiasis	2d day	Bronchopneumonia; rupture of wound requiring secondary operation
5. Chronic cholecystitis and cholelithiasis	4th day of pneumonia	Transduodenal exploration of ampulla; peritonitis ?
6. Chronic cholecystitis and cholelithiasis	42 days	Overlooked stone; transduodenal exploration of ampulla; septic course
7. Chronic cholecystitis and cholelithiasis	Sudden; 16 hrs.	Temperature, pulse and respiration like pneumonia
8. Chronic cholecystitis and cholelithiasis	10th day	Uremia
9. Acute cholecystitis and cholelithiasis	6th day	Uremia
10. Chronic cholecystitis and cholelithiasis	6th day	Uremia (early carcinoma; ducts)
11. Acute pancreatitis	27th day	Uremia; septic course
Cholecystostomy:		
1. Acute gangrenous perforated gallbladder, peritonitis	5-6 hrs. after abdominal drainage	Terminal case
Choledochostomy:		
1. Septic cholangitis, multiple liver abscesses, previous cholecystectomy and choledochostomy one year before	3 days	Septic course
2. Overlooked common duct stone; previous cholecystectomy and choledochostomy 5 months before	17th day	Postoperative hemorrhage; rupture of wound; asthenia
Drainage of Pancreas and Abdomen:		
1. Acute hemorrhagic pancreatitis	6 hours	
2. Acute hemorrhagic pancreatitis, gangrenous gallbladder	13th day	Septic course
3. Acute hemorrhagic pancreatitis	30 hours	
Attempted Laparotomy:		
1. Acute hemorrhagic pancreatitis	.....	Terminal case
2. Acute hemorrhagic pancreatitis	.....	Terminal case

Of the twenty-six fatalities, there were seven cases in which the patients were practically moribund on admission or so overwhelmed with sepsis that they succumbed either during operation or a few hours afterwards. It is questionable whether attempted operation in some of these cases was justifiable. Excluding those cases in which sepsis was the predominant feature, the most frequent postoperative complications leading to death were postoperative pneumonia and uremia. There were six cases with fatal outcome in which pneumonia — a postoperative pneumonia — seemed to be the causal factor. Ether was used in most of these cases and the anesthesia proceeded smoothly throughout the cases in question. Postoperative pulmonary complications, both minor and major, have not as a rule been more

frequent in gallbladder operations than in other operations on the upper abdomen in this clinic. There is required, however, a little deeper anesthesia for relaxation, and working under the diaphragm may cause some pulmonary embarrassment. The resulting pneumonia is undoubtedly due not only to ether, but to a combination of causes such as trauma, operative shock, preoperative pulmonary irritability, sepsis and irritation from ether inhalation. There were four deaths from uremia with complete suppression of urine following operation. None of these cases showed anything unusual in the urine preoperatively. None of these cases were emergency cases, and the suggestion is made of the advisability of having functional tests on all patients undergoing such operations, with a view to increasing therapeutically the functional capacity of the kidney, preoperatively, if it is found low.

Two hundred and one cases were heard from in response to follow-up letters for final results two to four years after operation. These are given in Table 8.

TABLE 8.—FINAL RESULTS

	Operation					
	Cholecystostomy	Per Cent.	Cholecystectomy	Per Cent.	Cholecystectomy, Choledochostomy	Per Cent.
Number of cases....	17	....	125	....	59	
Well.....	11	64.7	110	88.0	57	96.6
Improved.....	..	....	9	7.2		
Total well and improved.....	11	64.7	119	95.2	57	96.6
Unimproved.....	6 (secondary operation)	35.3	6	4.8	2	3.4

In this series there is evidently a larger percentage of cured cases among those with common duct complications requiring cholecystectomy and choledochostomy. This is due (1) to the fact that the error of diagnosis is less in these complicated cases in contrast to the number of normal gallbladders removed in the simpler cases, and (2) to the beneficial effect of long continued drainage of the biliary passages. This seems to confirm Archibald's observation that in the complicated cases of cholecysytitis and pancreatitis, long continued drainage of the common duct is followed by the persistence of fewer postoperative symptoms than in the undrained cases.

SUMMARY

1. Gallbladder disease — cholecystitis and cholelithiasis — is a disease of middle age occurring with special frequency in women and closely associated with the increasing incidence of pregnancy.

2. Many cases evidently originate in early age and persist with only vague indefinite symptoms until later in life.

3. Gallstones are due in all probability to a hematogenous infection, commonly streptococcal, of the gallbladder and biliary passages and are associated with an altered cholesterin content of the blood.

4. Common duct and pancreatic complication are of frequent occurrence in the long persisting cases.

5. There appears to be no special dilatation of the extrahepatic biliary passages in the slow obliteration of the gallbladder through chronic infective processes with fibrosis.

6. Recurrences are due mainly to overlooked or reformed stones, persistence of the original infection or to its extension as a chronic pancreatitis.

7. Injury to the biliary passages during operation is due to the rather frequent abnormalities in the blood vessels and biliary passages.

8. Cholecystectomy is the operation of choice in cholecystitis and cholelithiasis whenever feasible. There is a marked beneficial effect in the long continued drainage of the biliary passages in the complicated cases of cholecystitis and pancreatitis.

9. There is no special detrimental effect of cholecystectomy on the body economy.

10. There is an increasing mortality rate with the increase in the complications of disease. This is an argument for early diagnosis and operation.

OPEN PNEUMOTHORAX

AN EXPERIMENTAL STUDY OF THE FUNCTIONAL PATHOLOGY OF SUCKING CHEST WOUNDS

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I. INTRODUCTION.
II. METHODS.
III. RESULTS:
1. The mechanical changes in respiration.
2. The minute volume of respiration.
3. The respiratory gas exchange.
4. The carbon dioxid content of the blood.
5. The acid-base equilibrium of the blood.
IV. CLINICAL CORRELATION AND COMMENT.
V. CONCLUSIONS.

I. INTRODUCTION

Pneumothorax, opening externally in the form of the "sucking" chest wound of warfare, or as the result of operations on the chest, especially for empyema, is of fairly frequent occurrence and of very serious import. I have been unable to find in the literature much serious study of the functional changes which lead to the frequently fatal outcome. Therefore, further observations seemed appropriate. The present report deals with experimental pneumothorax in the rabbit. The features especially considered are the volume of air respired per minute; the respiratory exchange of oxygen and carbon dioxid and their relation, the respiratory quotient; the total carbon dioxid content of the blood; and the acid-base equilibrium of the blood. The changes in the circulation of the blood have not been studied because of the technical difficulties of determining the minute volume of cardiac output.

II. METHODS

Rabbits were used throughout the experiments. They were anesthetized with 5 c.c. of 20 per cent. urethane per kilogram, given by rectum. This dosage was varied a little for different lots of rabbits (depending on age, breed, etc), the aim being to secure a light degree of anesthesia, preserving at the same time a responsive respiratory center and active corneal reflexes. Owing to the lightness of the anesthesia, the preliminary operation for the introduction of tracheal and pleural cannulas was carried out under the influence of a few whiffs of ether. The same tracheal and pleural cannulas were used in all of the experiments. The specially devised pleural cannula was of

a slightly greater diameter than the tracheal cannula, so as to allow an easy exchange of air into and out of the pleura. A purse string suture was sewed around a small opening in the muscles between the ribs of the right side and drawn tight as the conically pointed cannula was plunged through the pleura. By means of this procedure the normal pleural pressure was not lost. After periods of pneumothorax a negative pressure could be induced and maintained in the pleura by closing the cannula. A routine negative pressure of 30 cm., indicated by a water manometer, was used during the periods designated as "closed," following the periods of pneumothorax. The first "normal" observations were always taken after the pleural cannula had been inserted, and before it was opened, allowing some time for the animal to become quiet, so as to avoid the effects of the operative hyperpnea, When blood was examined, it was obtained by aspiration through a needle from a previously exposed carotid artery. It may be said that after the necessary operative procedures had been completed the animals remained practically undisturbed. Their condition was further controlled by observing the rectal temperature from time to time. All of the animals used were in good condition. None had been previously starved or placed on special diets.

III. RESULTS

1. *Mechanical Changes in Respiration.*—When one pleural cavity is opened, the negative inspiratory pressure, as measured by a manometer, is reduced practically to zero. The lung on this side, owing to its elasticity, collapses more or less completely, but probably never entirely. The mediastinum, if sufficiently elastic, is drawn to the sound side, reducing the negative pressure on that side also, except as the animal may be able to compensate for it by increased respiratory effort. This compensation appears to be brought about by the animal's superimposing the respiratory movements on an average position of the chest more or less approaching the position at complete inspiration.

The decrease in the average degree of distention of the two lungs decreases the alveolar surface, and thus tends to encroach on the area through which the gases must diffuse into and out of the blood. In order to maintain or increase the difference between the partial pressure of the gases in the alveoli and in the blood, so as to increase the exchange of gas per unit area of alveolar surface, and thus to maintain a normal total exchange of gases, the alveoli must be hyperventilated. Furthermore, the "dead" space of the trachea and bronchi is increased in proportion to the active alveolar surface. There will be poorer ventilation of the alveoli in pneumothorax than under normal conditions by a tidal air in each case of a magnitude equaliy propor-

tional to the total volume of both the dead space and the alveoli. The bailing out, as it were, of the alveoli must be increased over the normal if the embarrassment of respiration due to pneumothorax is to be compensated for. The experiments of the next section will show what changes really occur in the volume of air respired per minute during pneumothorax as compared to the normal.

2. The Minute Volume of Respiration.—Immediately after the pleural cannula is opened, the quietly breathing animal is suddenly seized with an intense dyspnea. The change in the character of the respiratory movements is so marked that the volume of air respired per minute appears to be increased. A part of the increased muscular effort is undoubtedly wasted in moving the air in and out through the pleural cannula, and in attempting to ventilate the partially collapsed lungs which now possess a dead space of trachea and bronchi increased

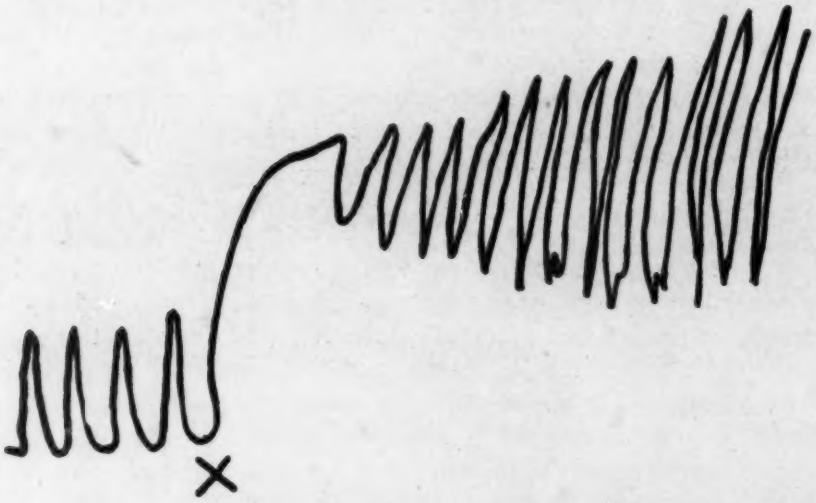

Fig. 1.—Tracing of contractions of slip of muscle of diaphragm. At X the pleura was opened. There followed an inspiratory tetanus, and then hyperpnea. (Taken from Henry Head.[1])

out of proportion to the area of active alveoli. The character of this dyspnea is illustrated by the accompanying tracing taken by Henry Head [1] in 1889 (Fig. 1). Studying another problem, Head observed the activity of the respiratory muscles, by tracing the movements of a slip of the muscle of the diaphragm. He found that when the pleura was opened there was an immediate inspiratory tetanus, followed shortly by a marked degree of hyperpnea.

We used two methods to study the changes produced in the minute volume of respiration. In Method A, the animal was placed in a

1. Head, Henry: J. Physiol. **10**:279, 1889.

large glass jar, with a lid which could be sealed air-tight. The tracheal and pleural cannulas were connected by rubber tubing with the outside. By means of a screw clamp whose shaft passed through the lid, the pleural cannula could be opened or closed without removing the lid of the bottle. The bottle was connected by rubber tubing to a Gad spirometer of small dimensions, carefully balanced and fitted with a light pointer for tracing on a kymograph. By this arrangement, a record of the changes in the volume of respiration was obtained, since on inspiration a volume of air, equal to the volume of air inspired from the outside, would be displaced from the bottle by the increase of the volume of the animal's thorax. On expiration the opposite would occur. In a few experiments the blood pressure was also recorded by a mercury manometer, in the usual manner.

In Method B, light aluminum valves, separating the inspired from the expired air, were attached to the tracheal cannula. The expired air was led to a Gad-Bohr spirometer of larger size than that used in

Fig. 2.—Minute volume of respiration taken by Method A: 1, thorax unopened; 2, pneumothorax produced.

Method A. With such an arrangement an obliquely rising line was drawn by the spirometer on the smoked drum. The steepness of this line indicated the minute volume, in some approximate proportion at least.

The results obtained were practically without variation. Both methods showed the minute volume to be decreased during pneumothorax. The results were rendered more certain by alternating periods of opened and closed thorax. The tracings in Figures 2, 3, 4, 5 and 6 are typical of the results obtained in seventeen experiments.

Figure 2 shows the first normal control, followed by the first period of pneumothorax. There was a decrease in the amplitude of respiration, together with a slight increase in rate. Careful calibration showed that the minute volume was decreased. Figure 3 shows four superimposed curves, sections of a tracing taken four times continuously around the kymograph. Reading from below upward,

the thorax was opened, closed, opened, closed. The "closed" tracings here presented were taken subsequent to pneumothorax, and indicate a ventilation greater than normal, in compensation for the conditions supervening during pneumothorax. Figure 4 shows periods of open, closed and opened thorax, with corresponding small, large and small minute volume, and with the blood pressure lower during the closed period.

By Method A, the minute volume was expressed by the product of the amplitude of the curves multiplied by their frequency. Both factors did not always change simultaneously and in the same direction. Therefore it was not always easy to estimate, except by very careful

Fig. 3.—Minute volume of respiration taken by Method B: O, open thorax; C, closed thorax. Read from below up.

calibration, the minute volume, although there was always a striking change in at least one of the factors. This difficulty was obviated by Method B, as just described. Here the minute volume was expressed directly by the obliquity of the curve. Figure 5 is an example of this. At the left, the uppermost curve represents part of a control (closed thorax). About the middle of the next curve, when the chest was opened, the curve immediately flattened. The next

Fig. 5.—Minute volume of respiration taken by Method B: artery; lower curve represents minute volume of respiration: 1, part of tracing taken during pneumothorax; 2, pleural cannula closed; 3, negative pressure produced in pleural cavity, and 4, pleural cannula again opened.

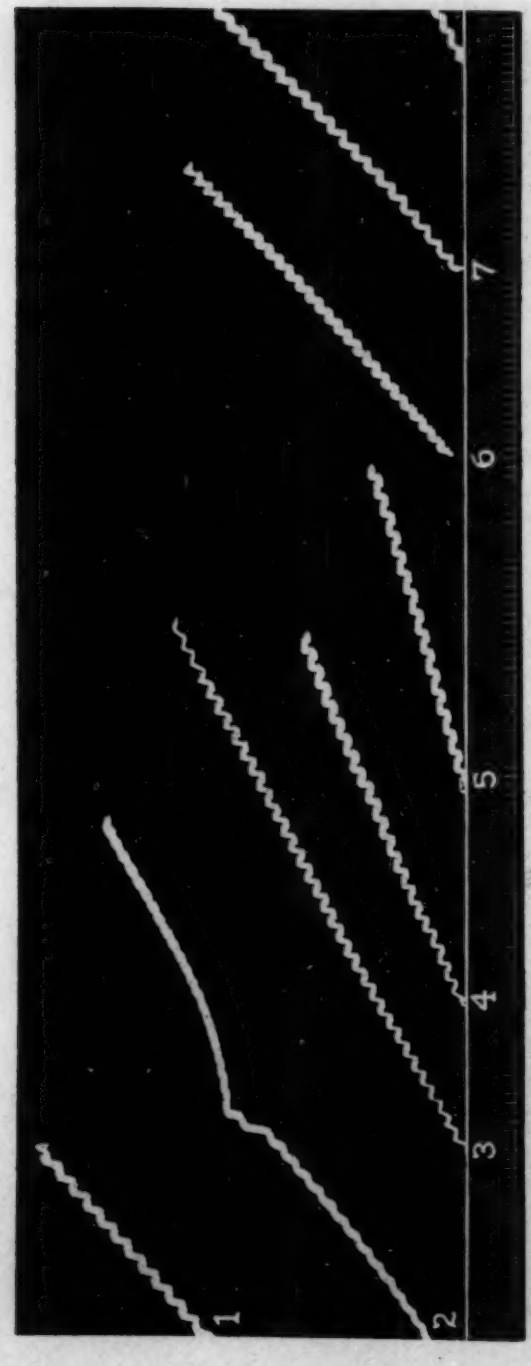

Fig. 5.—Minute volume of respiration taken by Method B.: 1, control; 2, control, with pneumothorax produced at middle of curve; 3, 4 and 5, taken during continuation of pneumothorax; 6 and 7, taken after pleural cannula had been closed.

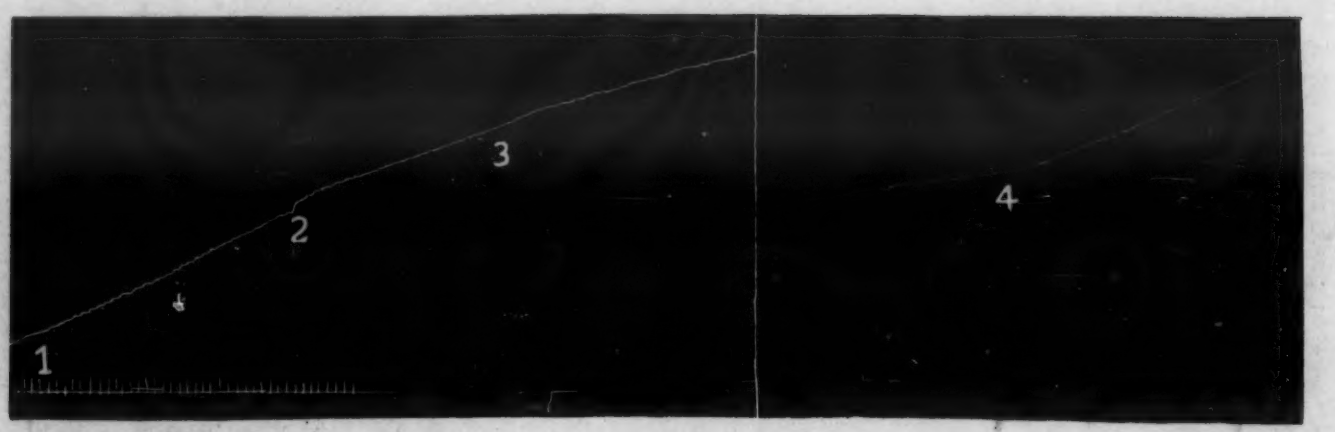

Fig. 6.—Minute volume by Method B: 1, control; 2, pleural cannula opened; 3, large opening cut in the thoracic wall; 4, opening closed with hand at the height of inspiration.

three curves are progressively flatter as the animal approached death. The tube in the chest was then closed and the two subsequent curves obtained. These show a much steeper ascent, indicating an approach toward the normal minute volume.

Figure 6 shows a curve which emphasizes the great importance of the dynamic factor of air rushing in and out of the pleural opening, as compared with the relative nonimportance of the static factor of the degree of pulmonary collapse. Starting at the left with a control, the pleural tube was opened and the curve flattened. An opening in the thorax, 5 or 6 cm. in diameter, was then made. The curve flattened a little more. The degree of the collapse of the lung could then be seen. By placing the hand over the opening at the height of the inspiratory phase, so as to develop the least possible negative pressure, and consequently the least possible distention of the lung, the curve immediately became steeper, and gained an obliquity approximating the control curve.

These results being constant, it accordingly seems justifiable to conclude that the rabbit is unable to compensate by means of an increased minute volume for the pathologic changes in the mechanics of the respiratory movements caused by open pneumothorax. The decreased ventilation observed suggests some abnormality in the exchange of gases between the blood and the outside air. This will be considered in the next section.

3. *The Respiratory Gas Exchange.*—The method adopted for the study of the respiratory exchange was that described by Benedict.[2] In the construction of our apparatus, we followed very closely the details of Benedict's description, into which it does not seem necessary to go now. Our oxygen was measured by a carefully calibrated Bohr gas meter, rather than by weighing. The animal was connected with the system by means of a three-way valve attached to the tracheal cannula.

The animals were of necessity under variable degrees of anesthesia. Because of the fatality of prolonged pneumothorax, the experiments were necessarily of short duration. Consequently, it was not possible to obtain values closely approximating a mean average. In order to obviate this statistical handicap, we have accepted only those experiments which, in the same animal, permitted one or more observations during alternate periods of one hour each of closed, open and closed thorax. In addition, only when the rectal temperature had remained close to normal were the experiments accepted. After many disappointments, experiments were accumulated that fulfilled these strict conditions in seven rabbits, in two of which the sequence was twice repeated, making a total of nine observations.

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2. Benedict, F. G.: Deutsch. Arch. f. klin. Med. **107**:156, 1912.

The results of these observations are presented in Table 1. In Table 2 are presented the averages for all closed thorax periods, and for periods before, during and after pneumothorax, with no regard for the separation of the constituent figures into separate experiments. I have calculated the mean error of these averages by the usual formula, and in Figure 7, I have plotted these averages flanked by lines representing plus or minus three times the mean error. It is seen

TABLE 1.—Respiratory Gases and Quotients in Pneumothorax *

Exp. No.	Carbon Dioxid	Oxygen	Respiratory Quotient	Exp. No.	Carbon Dioxid	Oxygen	Respiratory Quotient
1	351	384	0.91	2	382	559	0.68
	186*	344*	0.54*		205*	446*	0.46*
	149*	268*	0.55*		398	500	0.79
	216	222	0.97				
3	274	334	0.81	4	218	314	0.69
	302	435*	0.69*		197*	345*	0.57*
	288	320	0.89		239	345	0.69
	166*	310*	0.52*		196*	332*	0.59*
					216	327	0.66
5	294	344	0.85	6	369	510	0.72
	213*	374*	0.56*		295*	466*	0.63*
	309	343	0.89		297	409	0.72
					208*	365*	0.57*
					394	495	0.79
7	377	508	0.74				
	390*	552*	0.70*				
	388*	557*	0.69*				
	485	544	0.89				

* Values for carbon dioxid and oxygen are in cubic centimeters per kilogram per hour. Values followed by * indicate pneumothorax periods. All periods are one hour each and immediately follow each other.

TABLE 2.—Average Respiratory Gases and Quotients in Pneumothorax *

	Carbon Dioxid	Oxygen	Respiratory Quotient
All closed thorax experiments	317 ± 25	401 ± 23	.796 ± 22
Before pneumothorax	318 ± 19	414 ± 31	.775 ± 28
During pneumothorax	241 ± 22	399 ± 25	.593 ± 21
After pneumothorax	316 ± 91	389 ± 33	.815 ± 35

* The values in Table 1 are averaged without respect to their separation into individual experiments. The mean error follows each average.

that the average value for oxygen remained practically unchanged. There was a considerable fall in the carbon dioxid average during pneumothorax, associated with a greater absolute fall in the respiratory quotient during the same period. The feature whose significance seemed most valid appeared in the respiratory quotient, in which the upper range of the pneumothorax period was below the lower ranges of all the other periods. Figure 8 presents the logarithms of these averages in order to bring out the ratio or proportional features of

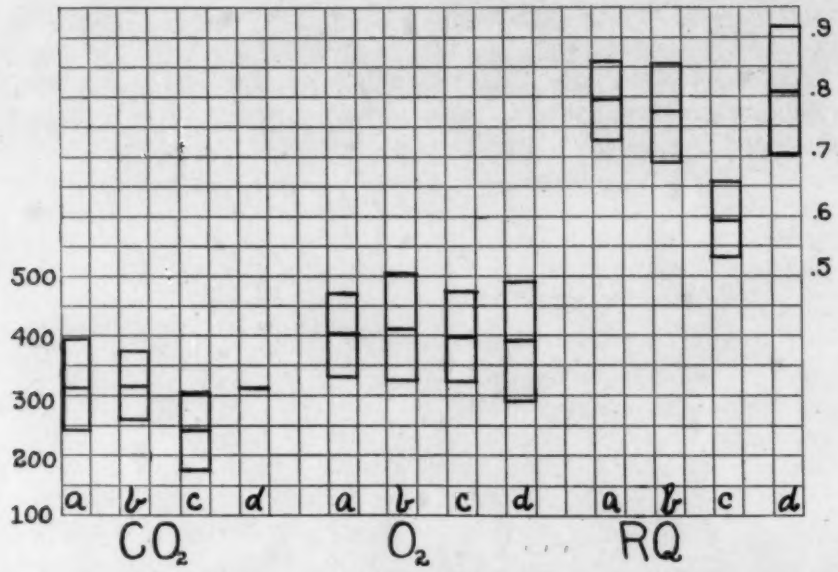

Fig. 7.—Average values of carbon dioxid, oxygen and respiratory quotient: *a*, of all periods during which the thorax was closed; *b*, of periods immediately preceding pneumothorax; *c*, of pneumothorax periods, and *d*, of periods immediately following pneumothorax. The averages are flanked above and below by three times their mean error, except for period *d* of carbon dioxid values, in which the dispersion of the constituent values about the average is too great to render this method of presentation available.

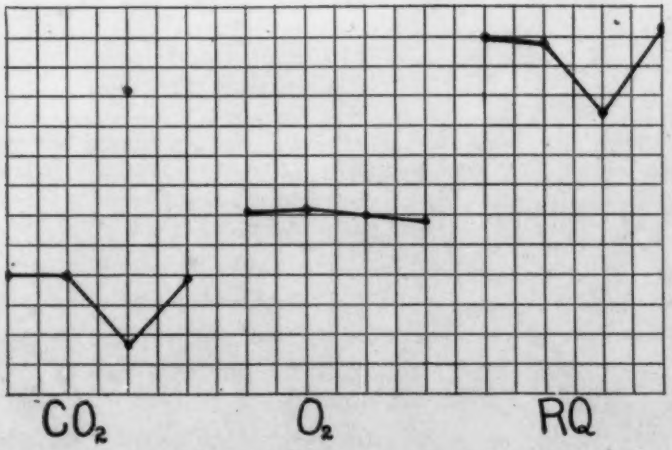

Fig. 8.—Averages of Figure 7 plotted on a logarithmic scale, so as to bring out the ratio features.

the changes. It is seen that the ratio of change in carbon dioxid is not far below that of the respiratory quotient, the oxygen remaining practically unchanged.

Averaging all of the observations, without regard to their relation to one another in individual experiments, is, of course, the least favorable procedure. It is accordingly encouraging that this method yielded what it did. In Table 3 are presented the averages with their mean error of the ratios of values in individual experiments, before, after and of both together, to the values during pneumothorax. The individual constituents of the averages are also given. It is seen that the ratio of carbon dioxid, before or after pneumothorax, to its value during pneumothorax is less than 100 per cent. in only three times out of nineteen. In these three instances it is only a little less, i. e., 90, 95 and 96 per cent. These values are probably insignificant,

TABLE 3.—Respiratory Gases and Quotients in Pneumothorax: Ratios of Values Before or After to Values During Pneumothorax ‡

Carbon Dioxid		Oxygen		Respiratory Quotient	
Before	After	Before	After	Before	After
188	145	111	88	169	175
186	194	125	112	148	173
90	95	76	78	118	129
173	121	103	100	170	121
110	110	91	98	121	112
123	145	104	91	117	158
138	100	92	88	149	115
125	208	109	135	114	139
142	125	112	98	127	127
96	...	92	...	105	...
137±10*	136±11*	101±4.1*	98±5.6*	133±7.0*	139±7.6*
136±7.7†		99±3.4†		136±5.1†	

* Averages.
† Averages of all values, both before and after.
‡ The values during pneumothorax are taken as 100.

coming within the range of experimental error. For oxygen, ten values are below and eight above, with one at 100 per cent., indicating no marked preponderance of change either way. The respiratory quotient is in every instance higher when the thorax is closed. As to the averages, it is striking that the oxygen ratio remains practically at 100 per cent. in all periods, while the averages of the ratios both before and after pneumothorax, for both carbon dioxid and the respiratory quotient are the same, 136 per cent. In Figure 9, I have plotted these averages of ratios, flanked by three times their mean error. In no instance does this range, either for carbon dioxid or for the respiratory quotient, extend down to the 100 per cent. line. The average values and ranges for oxygen are quite well centered about the 100 per cent. line.

In Figure 10, I have plotted the results of each experiment, again using the logarithms of the values in order to bring out the proportional changes. Each curve has its own base, but all are drawn to the same scale. These curves emphasize the extreme variability of the oxygen consumption and its relative small change from period to period. The much greater changes in carbon dioxid are brought out, together with the fact that in the few instances in which the value is higher during pneumothorax, it is only slightly so. In not a single instance does the quotient curve fail to fall during the pneumothorax periods, and usually quite markedly. It always rises after pneumothorax.

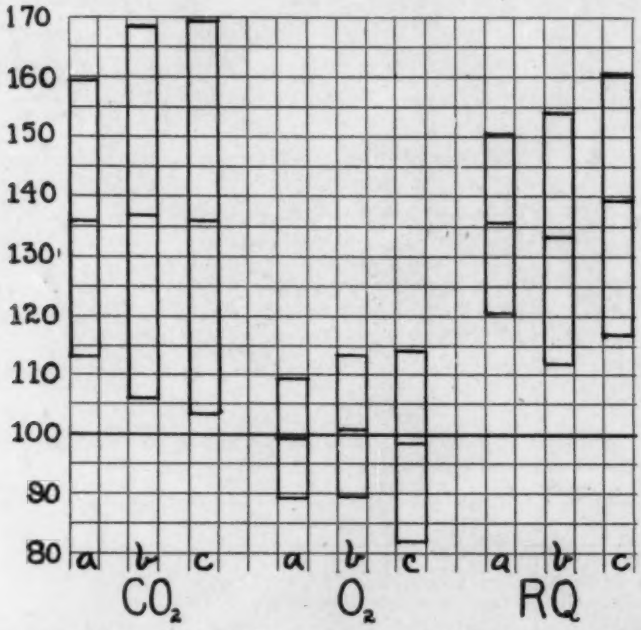

Fig. 9.—Averages of the ratios of carbon dioxid, oxygen and respiratory quotient, expressed in percentages, 100 per cent. indicating the value during pneumothorax: *a*, average of all closed periods; *b*, before, and *c*, after pneumothorax. The averages are flanked by three times their mean error.

A large fall in the quotient is always accompanied by a large fall in the carbon dioxid output.

The presentation in so many different ways of the values found in these experiments has seemed justifiable because of the relative small number of experiments. It should be appreciated that to obtain a sequential series of experiments of this type is difficult, and many of our attempts have been failures. The results obtained indicate that there is a constant reduction of the respiratory quotient during periods of pneumothorax. This appears to be due chiefly to a fall in the output of carbon dioxid. The changes in the consumption of oxygen are

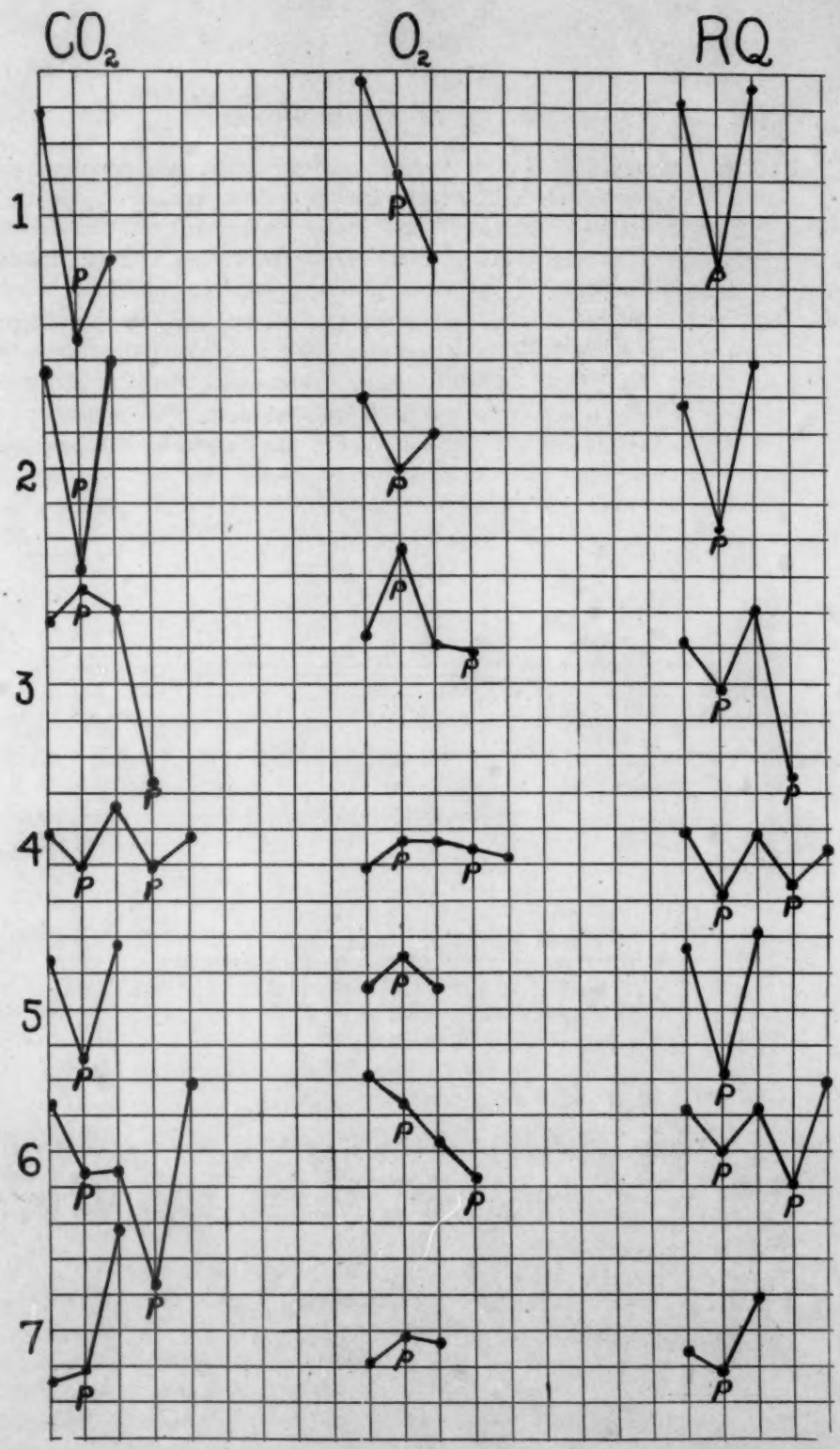

Fig. 10.—Values of the seven experiments plotted to the same logarithmic scale, but to different bases. Numerals at left indicate number of experiment. The dots labeled p indicate pneumothorax periods; unlabeled dots indicate closed periods.

of less magnitude, are more variable in direction, and seem not so intimately associated with the changes in the respiratory quotient.

The significance of these results may be advantageously viewed in the light of contemporary physiologic theory. As the ventilation of the pulmonary alveoli decreases, the tension of carbon dioxid rises, and that of oxygen falls. Accepting the theory that the passage of these gases between the lung and the blood is a physical process of diffusion,[3] at least over a wide range of functional demand, then the tension of these gases in the blood will tend to vary in the same direction as in the alveoli. In pneumothorax, the blood may be assumed to be exposed, as if in vitro, to an increased tension of carbon dioxid and a decreased tension of oxygen. In Figure 11 I have copied from Haldane, Meakins and Priestley [4] the so-called dissociation curves

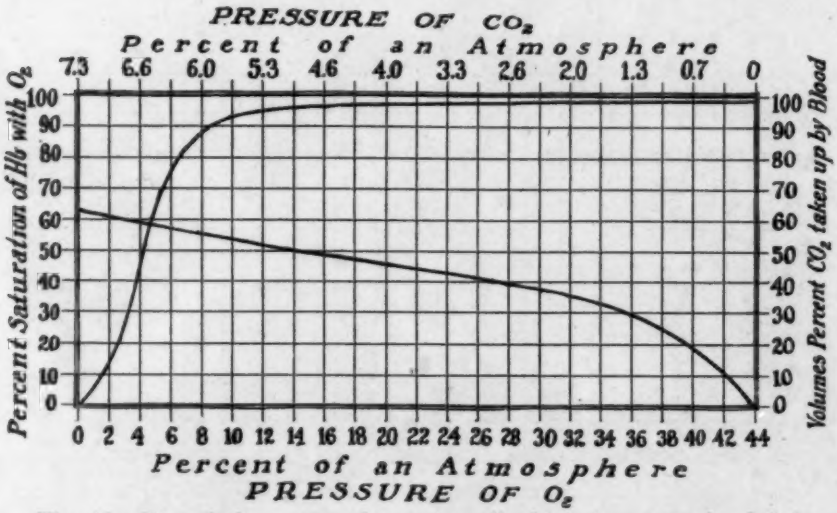
PRESSURE OF CO_2
Percent of an Atmosphere
7.3 6.6 6.0 5.3 4.6 4.0 3.3 2.6 2.0 1.3 0.7 0
Percent Saturation of Hb with O_2
Volumes Percent CO_2 taken up by Blood
100 90 80 70 60 50 40 30 20 10 0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Percent of an Atmosphere
PRESSURE OF O_2

Fig. 11.—Dissociation curves for carbon dioxid and oxygen (copied from Haldane, Meakins and Priestley [4]).

for carbon dioxid and oxygen. These curves express the proportion between the amount of gas held by the blood in combination and the pressure or tension of the gas in the atmosphere to which the blood is exposed. The curve for carbon dioxid is, over a wide range, a steadily ascending straight line, indicating that as the tension is increased by equal increments the amount of carbon dioxid held by the blood in combination is increased by a certain fixed proportion. In other words, the blood has a large storage capacity for carbon

3. Barcroft, Joseph: The Respiratory Functions of the Blood, Cambridge University Press, 1914.

4. Haldane, J. S., Meakins, J. C., and Priestley, J. G.: J. Physiol. **52**:433 (May) 1919.

dioxid. However, the oxygen curve has a different conformation. Through a wide range it is almost horizontal, i. e., parallel with the abscissa. This means that as the tension of oxygen is decreased the amount of oxygen combined by the blood is decreased very little over a considerable range. Thus for a certain distance, conditions are adjusted for a more or less adequate absorption of oxygen, but for an increasingly impaired excretion of carbon dioxid. This situation is in harmony with the low respiratory quotients we have found to occur during pneumothorax. If the tension of oxygen is still further decreased, to a point where the curve begins to fall rapidly, then the absorption of oxygen tends temporarily to be decreased, so far as the blood becomes less saturated with oxygen. But this effect will be only transitory, since, within wide limits, the consumption of oxygen is regulated by the demands of metabolism, and not by the quantity of oxygen in the blood. That is, if the level of metabolic activity does not change, the necessary amount of oxygen will be removed from the partially saturated blood, and the blood will return to the lung in a higher degree of unsaturation than is normally the case. Its oxygen tension will be so low that in spite of the low tension in the alveolar air, an efficient slope of pressure will be maintained from the alveoli to the blood, and the consumption of oxygen will not be reduced. Such is the explanation of the values for oxygen absorption yielded by many of our experiments. Of course, if the reduction of oxygen tension in the alveoli becomes too low, the demands of the tissues will not be met and asphyxia will result. There is no evidence that this is a major factor in pneumothorax.

The invariability of the decrease of the respiratory quotient during pneumothorax seems entirely explainable by the above theory. This theory explains also the relatively constant decrease in carbon dioxid elimination. The variable amount of oxygen consumption, so far as it occurs beyond the limits of experimental error, would seem to find its usual explanation in the variable levels of metabolism associated with variable attempts at compensation on the part of the respiratory muscles. A lightly anesthetized animal, with an active respiratory center, will respond to pneumothorax with a strenuous respiratory effort; will demand more oxygen, and be able, up to a certain degree, to take in more oxygen. An animal too deeply anesthetized, or injured too much by the changes which occur in the blood as the result of the pneumothorax, will be capable of less respiratory effort, or may even approach respiratory failure, when, of course, oxygen consumption will be decreased. Carbon dioxid production will rise and fall with oxygen consumption, but the difficulty of its elimination will always lead to its accumulation in the blood and tissues. The few

small increases in carbon dioxid elimination that I have found during pneumothorax are probably within the range of experimental error. The constant fall of the respiratory quotient would indicate that the elimination of carbon dioxid is not in proportion to its production, and that accumulation in the blood must result.

This section may be summarized as follows: The absolute amount of oxygen absorbed varies in either direction, determined largely by the metabolic demands of the animal. While carbon dioxid production varies with the oxygen consumption, its elimination, at least relatively, and probably absolutely, is always reduced. The respiratory quotient is invariably decreased.

4. *The Carbon Dioxid Content of the Blood.*—The retention of carbon dioxid shown by the study of the respiratory exchange suggested confirmation by the direct determination of the carbon dioxid content of the blood. These determinations were made by the Barcroft-Haldane apparatus.[5] The usual procedure of taking observations during alternating periods of closed and opened thorax was followed. The results are exhibited as part of Table 6. Comment is hardly necessary. The carbon dioxid content of the blood in all five experiments is higher during the pneumothorax period than in either the normal control period, or in the period of closed thorax after the pneumothorax. These results are in complete harmony with those of the previous section.

5. *The Acid-Base Equilibrium of the Blood.*—The retention of carbon dioxid suggested the possibility that it might reach an amount sufficient to disturb the normal acid-base equilibrium of the blood and produce an acidosis in the sense of an increased hydrogen ion concentration. The dialysis-colorimetric method of Levy, Rowntree and Marriott[6] was used. The blood was drawn from the carotid artery through a specially devised needle into a record syringe containing a little oxalate to prevent clotting. Three c.c. of blood were dialyzed for five minutes in tubes carefully stoppered. Many of the readings were taken independently by two observers. Control observations, before pneumothorax was induced, gave readings for p_H ranging from 7.35 to 7.5. After the production of pneumothorax, there was always a movement of the p_H toward the acid side, i. e., a reduction in its value. Values as low as 6.9 were observed. Such low values are, of course, only momentarily compatible with life, and the animals all died unless relieved by closing the opening in the

5. Barcroft and Haldane: J. Physiol. **28**:233, 1902.

6. Levy, R. L., Rowntree, L. G., and Marriott, W. M.: A Simple Method for Determining Variations in the Hydrogen-Ion Concentration of the Blood, Arch. Int. Med. **16**:389 (Sept.) 1915.

chest. The rate at which the acidity of the blood increased, the degree it reached and the time of death of the animal varied considerably with different animals. Some animals died in fifteen or twenty minutes with a very low p_H, i. e., increased "acidity." Others lived more than an hour with little change in the reaction. The cause of these variations is not certain. It would seem that variable degrees of anesthesia would be one of the main factors. Other factors are pliability of the mediastinum, age of the animal and diet.

TABLE 4.—HYDROGEN ION CONCENTRATION (p_H VALUE) OF THE BLOOD IN PNEUMOTHORAX *

	Thorax					
Normal	Open	Closed	Open	Closed	Open	Closed
7.5	7.3	7.4	7.2	7.3	...	...
7.5	7.3	7.5	7.3	7.4	...	...
7.35	7.05	7.35	...	...	...	...
7.3	7.15	7.2	...	...	...	...
7.5	7.35	7.45	7.4	...	...	...
7.6	7.25	7.45	7.2	...	...	...
7.5	7.1	7.4	7.1	6.9	died in four minutes	
7.45	7.35	7.4	...	...	...	...
7.5	7.4	7.5	7.4	7.5	7.25	7.3

* Each horizontal row of figures consists of the values observed during alternate periods of closed and open thorax in the same animal.

The tendency toward acidity of the blood in pneumothorax was confirmed in nine out of a series of twenty-eight experiments in which the changes in the hydrogen ion concentration (p_H) were followed in successive and alternating periods of pneumothorax and of closed chest. In nine, or approximately one third of these experiments, a movement back and forth of p_H, corresponding to the alternate periods of closed and open chest, was obtained. The results of these nine experiments are presented in Table 4. These results indicate a definite influence of pneumothorax on the reaction of the blood. The inability to obtain such a correlated sequence in the rest of the experiments is explained by inopportune withdrawal of blood. Probably many times the blood was taken too soon after the induction of pneumothorax and before the change in hydrogen ion concentration had taken place. In some instances, the blood was undoubtedly taken so late that the animal either died or was unable to overcome the acidosis in the ensuing period of "closed thorax." In other words, the ratio of 1:3 successful sequences is mainly a measure of what might be termed the "clinical" judgment of the observer as to the condition of the animal at the time the various steps of the experiment were taken. In Table 5 are given the results of four additional experiments, in which "clinical" judgment was aided by the simultaneous recording of the minute volume of respiration. These results were read independently by two observers and show a small series in which

successful sequences were obtained in 100 per cent. of the trials. Therefore it seems justifiable to conclude that the demonstration of such alternating changes in the hydrogen ion concentration of the blood in a considerable proportion of experiments is proof of the intimate relation of pneumothorax to these changes, i. e., associated with pneumothorax there is an acidosis in the sense of an increased hydrogen ion concentration (reduced p_H).

TABLE 5.—p_H VALUES IN FOUR SUCCESSIVE EXPERIMENTS CONTROLLED BY RECORDING MINUTE VOLUME OF RESPIRATION

Control	Thorax Open	Thorax Closed
7.35	7.05	7:15
7.45	7.15	7.35
7.35	7.25	7.4
7.4	7.2	7.4

TABLE 6.—CARBON DIOXID CONTENT AND REACTION OF THE BLOOD IN PNEUMOTHORAX

Exp. No.		Thorax				
		Control	Open	Closed	Open	Closed
1	Vol. % CO_2	47	60	54–46	60	47
2	Vol. % CO_2	70	77	56	90	*
	p_H	7.35	7.1	7.05	7.05	
3	Vol. % CO_2	63	95	73		
	p_H	7.4	7.15	7.35		
4	Vol. % CO_2	49	73	53–50		
	p_H	7.35	7.25	7.25–7.4		
5	Vol. % CO_2	53	70	55		
	p_H	7.4	7.2	7.4		

* Animal nearly died at first pneumothorax.

The previous experiments having shown that there is in pneumothorax an accumulation of carbon dioxid in the blood and an increased hydrogen ion concentration, it seemed desirable to secure simultaneous data as to the association of these two factors. Five experiments were performed, following the usual sequential alternation. Here again were encountered the technical difficulties of a procedure which brought the animal close to death during the pneumothorax periods. Nevertheless, in the last three experiments, the correlation of chest condition with the carbon dioxid content and the hydrogen ion concentration of the blood is quite close. In the second experiment the animal nearly died several times, and the p_H values were not obtained in the first experiment. It should be added that the determinations of the p^H and of the volume per cent. of carbon dioxid were not strictly simultaneous, there often being an interval of several minutes.

Taking into consideration all of the evidence presented as to the retention of carbon dioxid and the appearance of an increased hydrogen ion concentration of the blood during periods of pneumothorax, it would seem permissible to conclude that an "acidosis" develops which, in part at least, is due to the retention of carbon dioxid. That in addition there may appear fixed acids, we were unable to determine. The oxygen consumption in some of the experiments was low, and, in relation to the metabolic demands, may have been sufficiently low to produce asphyxia of such a degree as to permit the appearance of unoxidized acid metabolites. Direct proof of the presence of fixed acid was sought by determining the hydrogen ion concentration after freeing the blood of its carbon dioxid by means of a vacuum, and then exposing it to a constant tension of carbon dioxid. The results were wholly equivocal. It is suggestive that during the intervals of closed chest after pneumothorax the blood carbonate was never very low. Such would be the case in the presence of fixed acids, since these would tend to displace the carbon dioxid from union with base, raise the amount of free carbon dioxid and its tension in the blood, and hasten its excretion through the lung. It may be objected that the time interval was too short for the washing out of the carbon dioxid to a low level. In only one instance during periods of from twenty-five to sixty minutes did the total carbon dioxid content fall below 50 per cent. by volume. While it does not seem likely that fixed acids play a great rôle in the production of the acidosis of pneumothorax, their existence cannot be disproved by the data here submitted.

We conclude then that an "acidosis" appears during pneumothorax, associated with, and in large part due to, a retention of carbon dioxid. The rôle of fixed acid is not solved.

IV. CLINICAL CORRELATION AND COMMENT

The direct transfer to man of the results obtained in this investigation on the rabbit cannot be made without due consideration of existing physiological differences. Being herbivorous, the rabbit is more susceptible to acid intoxication, because it is less able to deviate ammonia from urea formation in order to neutralize acid. While the effect of pneumothorax on the minute volume and the respiratory exchange would quite likely be similar, it would seem that the appearance of an acidosis associated with an increased carbon dioxid content of the blood would be at least more fully compensated for in the carnivora. At any rate, it is interesting to apply the analogy to the problems encountered in the clinic.

The most common clinical procedure which produces a mechanical respiratory condition analogous to experimental pneumothorax in the rabbit is the operation for empyema. It is the experience of surgery

that patients may die during operation for empyema because of rupture of pus into a bronchus, with flooding of the lungs. According to Capps and Lewis [7] the cause of death may sometimes be due to reflex stimulation of the vagus, especially when the custom of washing out the pleural cavity is practiced. However, there is another type of death, which is not so sudden, and which usually occurs after the patient has been returned to the ward. An explanation of this type of death is suggested by the experimental work just reported. I refer to the patient who has been rolled partly over and the thorax quite well drained of pus. A large open tube has been placed in the opening in the chest wall, and the exposed end covered with a dry gauze dressing. Here we have all the conditions of an open pneumothorax, with air rushing in and out of the tube. There are several possible reasons why the mortality has not been greater. First, unless the empyema is an early one, the mediastinum is stiffened by the inflammatory exudate and invasion, so that the lung on the sound side is competent to meet the respiratory demands. Second, if the pus is not too thoroughly emptied at the time of operation, it will soon fill the tube and saturate the dressings, and thus prevent the free exchange of air through the tube. I have had two experiences with patients who were doing badly with dry open drainage tubes, but who improved by simply clamping the tube. In children, especially, is this condition likely to develop, due perhaps to the greater pliability of the mediastinum, which permits the effect of a unilateral pneumothorax to be more readily transmitted to the sound lung. General anesthesia, by lowering the activity of the respiratory center, would tend to augment the dangers.

The results of this work as applied to the operation for empyema would suggest these advantageous procedures:

1. In early cases the aspiration of the pus through a needle for a few days in order to allow time for stiffening of the mediastinum.

2. The use of local, instead of general, anesthesia.

3. Closer observation of the patients for the first few hours after operation.

4. The incomplete removal of pus at the operating table.

5. The temporary application of a Politzer bag to the drainage tube, by which a "sucking" wound is prevented and into which the pus may drain.

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7. Capps, J. A., and Lewis, D. D.: Blood-Pressure-Lowering Reflexes from Irrigation of the Chest in Empyema, Arch. Int. Med. **2**:166 (Sept.) 1908; Surg. Gynec. & Obst. **7**:243, 1908.

6. The probably unnecessary refinement of the use of negative pressure per se.

In any case it will not be long before the formation of adhesions and the plastic exudate will prevent the development of this condition.

The ability to operate on the lung without the use of positive intrapulmonary pressure may be raised as evidence against the possible occurrence in man of the conditions found in these experiments. However, it must be pointed out that when the lung itself has been the site of exploration or operation, it has usually been pulled up into the pleural opening, thus preventing an open sucking pneumothorax. Further, it is to be remembered that a considerable time interval is necessary for the development of this condition, even in the rabbit. In any case it should be borne in mind that the major danger lies neither in the collapse of the lung, nor in a closed pneumothorax, but in the deviation of the muscular respiratory effort, normally used to move air in and out of the trachea, to the moving of air in and out of the pleural opening.

V. CONCLUSIONS

1. Experimental open pneumothorax in rabbits causes an intense dyspnea, provided the anesthetic is not too deep, and death, if unrelieved by closure of the thoracic opening.

2. The volume of air respired per minute is decreased despite the increased respiratory effort.

3. The rate of oxygen consumption is variable, due probably to variable compensatory muscular action rather than to impaired gaseous exchange between lung and blood.

4. The excretion of carbon dioxid is impaired, often to a great degree.

5. The respiratory quotient is constantly reduced.

6. There is an increase in the total carbon dioxid content of the blood, and at the same time an increase in the hydrogen ion concentration.

7. These functional changes are important in open chest wounds, in the operation for empyema and related surgical conditions.

Since sending this manuscript to the publisher my attention has been called through a recent article to the work of Evarts A. Graham and Richard D. Bell, published in the War Medicine Supplement of the *American Journal of the Medical Sciences*, pp. 156-839, December, 1918. They report an extended experimental study of the relation between the pressure within one pleural cavity and changes of pressure artificially produced within the other pleural cavity. They show a close correspondence. My view, based on only a few experiments, and on a theoretical deduction from the visible flaccidity of a considerable portion of the mediastinum, is in entire agreement with theirs.

They have also studied the influence of the size of the pleural opening, showing that up to a certain size the condition is not fatal. It may be well to repeat that in my work the same pleural and tracheal cannulas were used in all the experiments, and were so related in size that the pneumothorax was always fatal, unless relieved.

This work was made possible by the facilities offered by the Cushing Laboratory of Experimental Medicine, the Physiological Laboratory of Western Reserve University, and the laboratories of the university clinic at the Cleveland City Hospital.

OBSERVATIONS ON THE BLOOD PRESSURE IN CASES OF PROSTATIC OBSTRUCTION

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During the last two years we have made a study of the blood pressure changes which occurred during the hospital management of patients suffering from prostatic obstruction.

The original object of these observations was to obtain, if possible, additional data which might assist us in determining the most advantageous method of preparing such patients for operation as well as the most suitable time for undertaking such an operation. Also, observations on the blood pressure of patients who have been relieved of their urinary obstruction for some time have revealed findings worthy of note.

This report comprises the results of the study of fifty-six patients with urinary retention due to prostatic obstruction, fifty-five of whom were operated on. The average age of this group was 61 years. The oldest patient was 86 and the youngest 46 years of age.

Prior to the estimation of the amount of residual urine, the blood pressure reading was recorded. A blood pressure reading was made every twenty-four hours for four days, and then every second day during the patient's stay in the hospital. Whenever possible the same house officer made all the readings throughout the entire hospital management of the individual case. He used the same standard type of mercury manometer to record all of the readings.

EFFECT OF DRAINAGE OF THE BLADDER

Sudden Fall in Blood Pressure.—When the bladder is kept at complete rest by an indwelling catheter, or by suprapubic cystotomy, a very appreciable fall in blood pressure occurs during the first twenty-four hours. In this series, the average fall in systolic blood pressure was 40 mm. of mercury at the end of this time. The average fall in diastolic blood pressure was 14 mm. of mercury.

The most marked diminution occurred in those patients who presented themselves with a marked hypertension, in nearly every instance associated with a considerable amount of residual urine (400 or more cubic centimeters). To a great extent the degree of fall seemed to depend almost entirely on two things: the quantity of residual urine; and the degree of reduction of renal function. The presence or absence of infection of the urinary tract made no obvious

difference in the degree of blood pressure change, nor was there any relative difference noted between those patients drained by suprapubic cystotomy and those in whom drainage had been established by an inlying urethral catheter. In all cases, when possible, the patient was urged to sit up in a chair for a time each day, and in most instances to walk about.

The greatest drop in systolic pressure during the first twenty-four hours after constant drainage was 85 mm., and in diastolic, 45 mm.

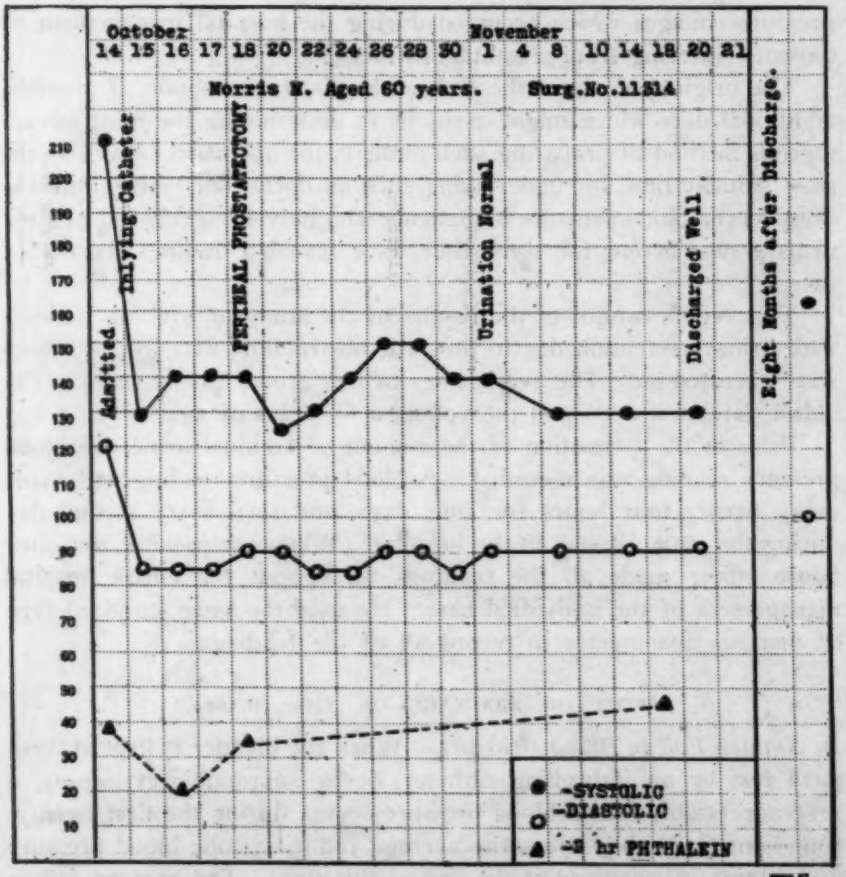

Chart 1.—Sudden fall in blood pressure on constant drainage with a rapid subsequent establishment of a fixed level. Postoperative fall was insignificant.

In 25 per cent. of the cases there was no fall in diastolic pressure at all, although 15 per cent. of these patients had an appreciable decrease in the systolic pressure. The six patients in whom there was no blood pressure change following drainage were all persons with a very small amount of residual urine, four of whom had an obstruction of the so-called "median bar" type.

In no instance did the blood pressure readings show an elevation on the second day as compared with the first day after keeping the bladder at rest. In 60 per cent. of the cases the systolic blood pressure continued to fall during the second twenty-four hours with an average of 17 mm. of mercury. In 40 per cent. there was no further reduction in systolic pressure and in 85 per cent. no decrease at all in diastolic pressure during this time.

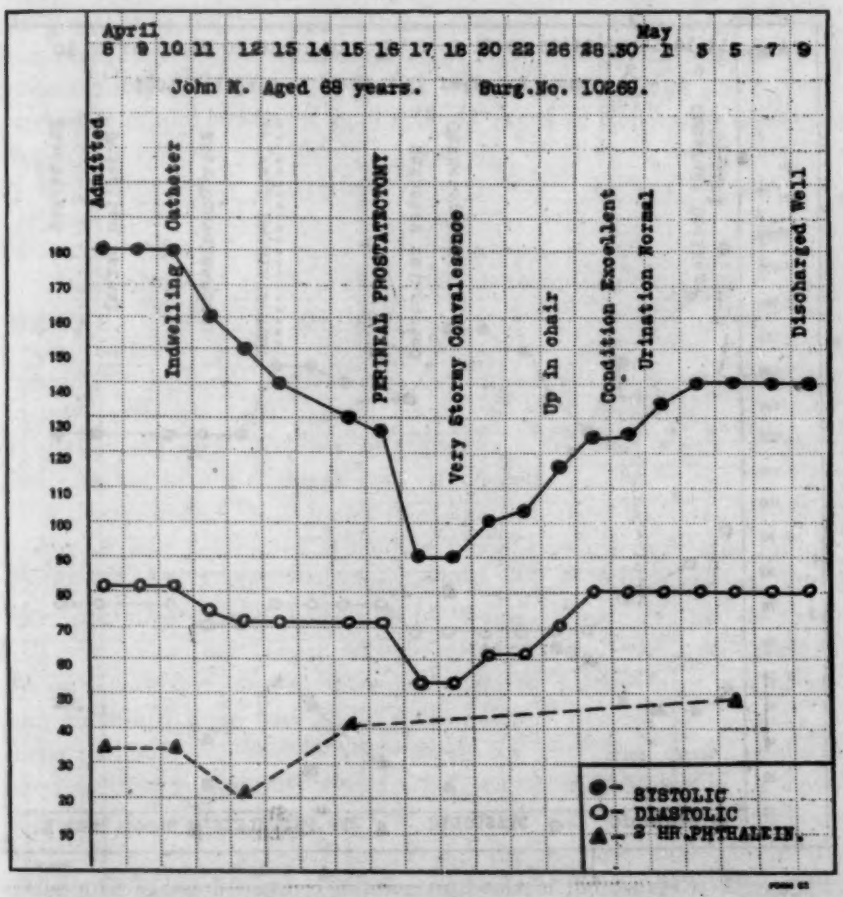

Chart 2.—Gradual fall in blood pressure on constant drainage. Operation, undertaken while the pressure was still falling, resulted in a marked decrease in pulse pressure.

There was no further fall in blood pressure in 75 per cent. of these cases after the second day of drainage. However, in the remaining 25 per cent. the pressure did continue to fall for one or several days and averaged a total decrease during this time of 15 mm. of mercury.

It was early noted that patients operated on at a time when the blood pressure was still showing a slight decrease each day, even though the pressure was accompanied by satisfactory renal function, showed a postoperative fall in blood pressure greater than seemed normally commensurate with the degree of operative disturbance.

This suggested the possibility that we were operating on these patients without a sufficiently prolonged preoperative management,

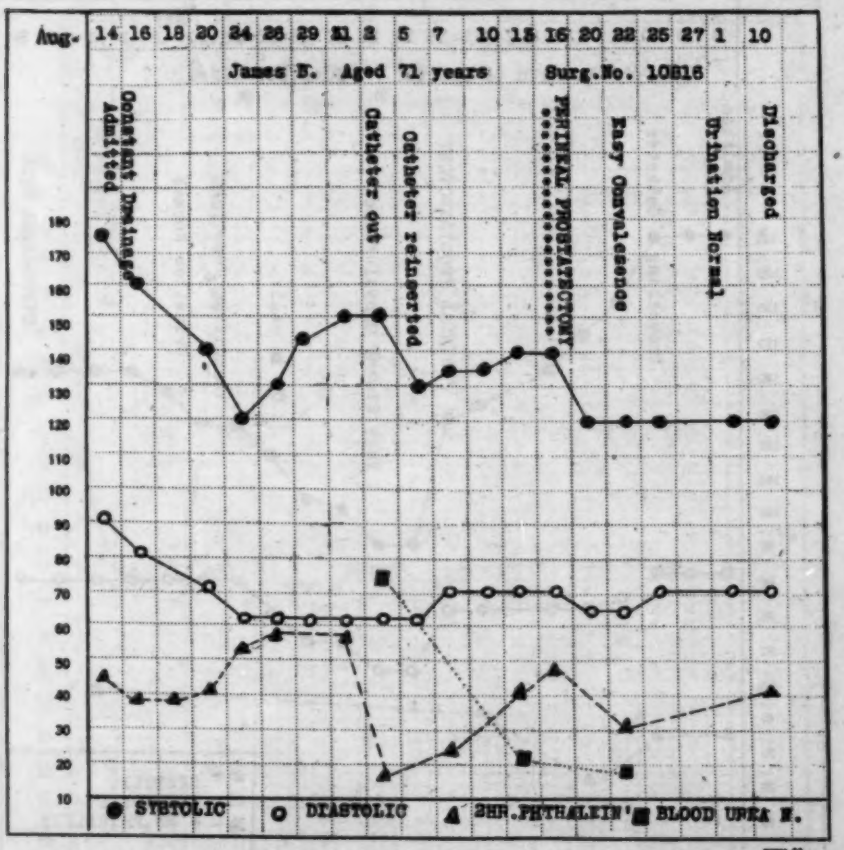

Chart 3.—Gradual fall in blood pressure on constant drainage with subsequent rise. Cessation of drainage for twelve hours was accompanied by a sudden fall in blood pressure associated with a marked decrease in renal function when the catheter was reinserted.

despite the fact that their general condition seemed satisfactory and their renal function entirely adequate. So, after this observation and in order that we might draw conclusions, no patient was operated on until his blood pressure had maintained a definite level for at least four days.

Establishment of a Fixed Blood Pressure Level on Continued Drainage.—When the patients were kept on satisfactory drainage, 60 per cent. of them had a subsequent rise in blood pressure after the period of decline. This average rise in systolic pressure was 16 mm. and in diastolic, 5 mm. of mercury.

In all but two patients observed, the blood pressure reached a constant level in from four days to two weeks and did not vary from this level over 5 mm. of mercury in the daily readings regardless of the duration of the drainage period. It must be emphasized, however, that any interruption, or insufficiency, of drainage for a period of more than from six to eight hours will frequently bring about very marked and rapid changes in the blood pressure and renal function. In the rare instance in which this interruption occurred, a reproduction of the entire series of relative blood pressure changes occurred in the same manner as when the patient was first placed on drainage, except that a fixed level was reached in a much shorter period of time.

The conclusions to be drawn from these observations are that on continued drainage of the bladder the blood pressure within two weeks maintains a level, or "equilibrium," at which time the renal function is restored to the greatest extent possible, and that the patient is in the best general condition for operation. This new level is in the great majority of instances a definitely lower one than that existing before drainage was established.

Postoperative Fall in Blood Pressure.—In the four cases in which operation was performed while the blood pressure was still falling, the decrease in systolic pressure during the first twenty-four hours after operation averaged from 80 to 30 mm. of mercury and from 40 to 5 mm., diastolic. There was therefore a considerable reduction in the pulse pressure, and rigorous postoperative management was necessary to return these patients to a normal convalescence. Whereas in those patients who had been prepared for operation until the blood pressure had maintained a definite fixed level, the degree of postoperative fall was surprisingly insignificant; 25 per cent. having no decrease in blood pressure at all and the average total fall in the remainder being 10 mm., systolic, and 6 mm., diastolic. There was therefore practically no change in the pulse pressure and the immediate convalescence was relatively easy.

Convalescent Period.—The relative blood pressure changes after operation varied considerably. Twenty per cent. of the patients had no subsequent rise and were discharged from the hospital with the blood pressure at the same level as it had been twenty-four hours after operation. The rest had a subsequent rise of from 10 to 40 mm. of mercury. In only one instance did a patient leave the hospital with

a higher blood pressure than he had had before preliminary bladder drainage. Ten per cent. left the hospital with the blood pressure at the same level as it had been on admission. The rest were discharged with the systolic blood pressure ranging from 80 to 15 mm. of mercury lower than before being placed on bladder drainage.

Subsequent Blood Pressure.—The blood pressure readings of thirty of the patients in this series have been recorded since their discharge

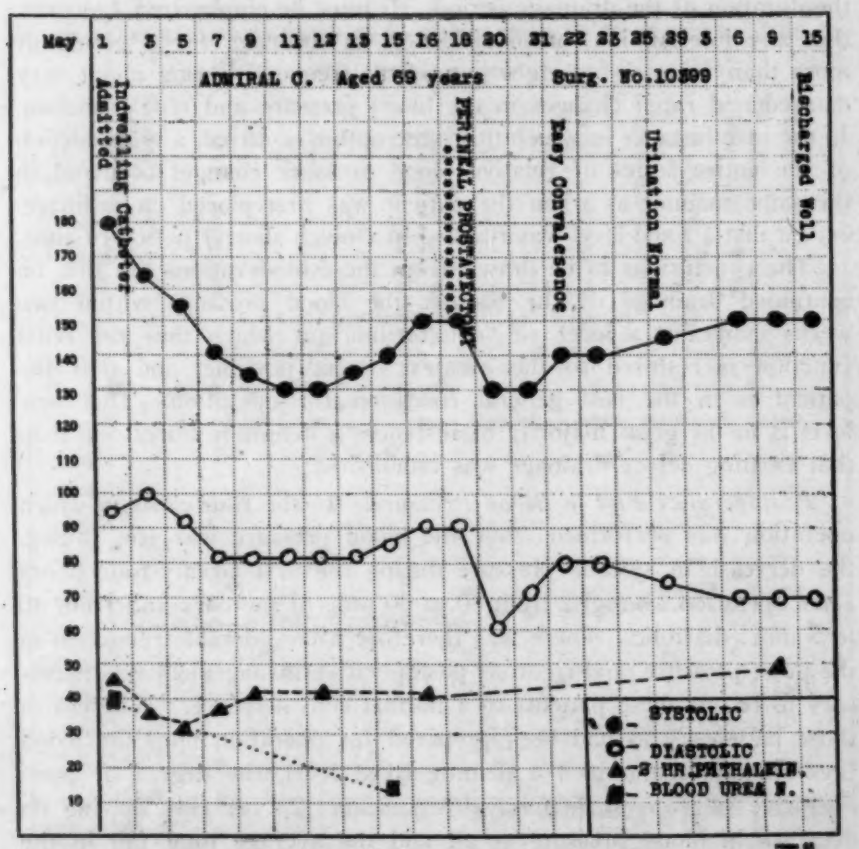

Chart 4.—Gradual fall in blood pressure on constant drainage associated with marked improvement in renal function. Operation caused no decrease in pulse pressure.

from the hospital. The period of observation has ranged from one to seventeen months.

Two patients now have a systolic pressure 20 mm. higher than before the urinary retention was relieved, but neither of these patients has a blood pressure higher than that which would be considered normal for his age.

Five patients have a systolic pressure maintaining the same level which was recorded on their original admission for treatment. Only two of these have an abnormally elevated blood pressure, and in both there is definite cardiac hypertrophy with valvular disease.

Twenty-three of these patients have a blood pressure which has continued at practically the same level as that which was estimated on their discharge from the hospital. On comparing their present blood

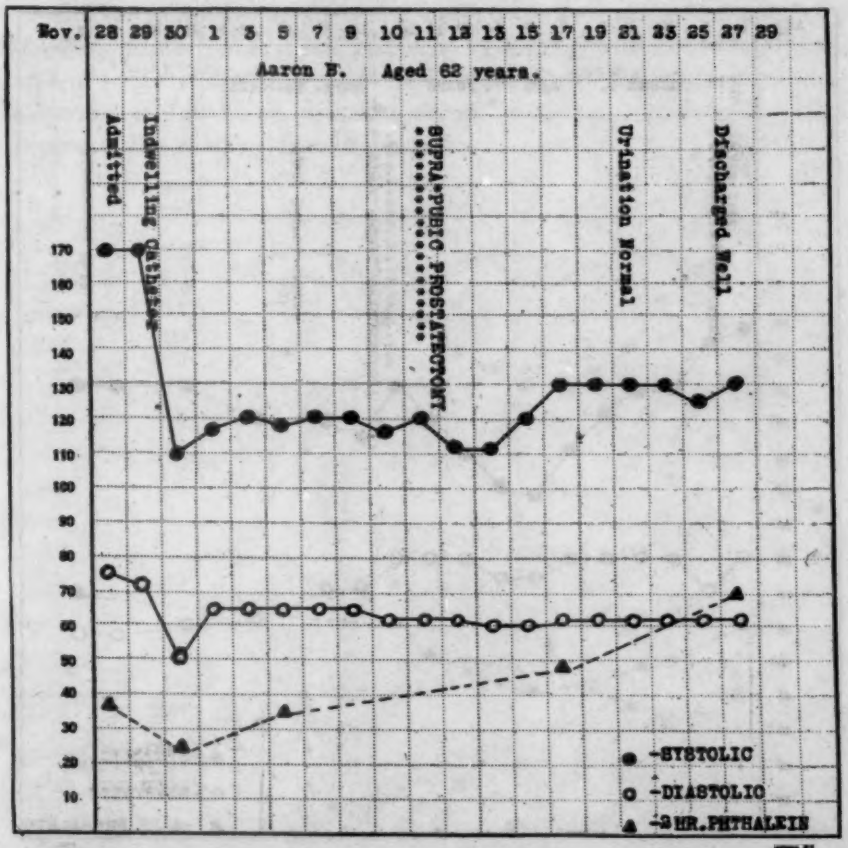

Chart 5.—Sudden fall in blood pressure on constant drainage with rapid establishment of a fixed level. Very slight postoperative fall in pulse pressure.

pressure readings with those made prior to any attempt at the relief of the urinary retention, we find that their systolic pressure is now maintained at a level which shows an average decrease of from 65 to 10 mm. of mercury. Of this number, sixteen patients had a definite hypertension with a systolic blood pressure ranging from 290 mm. to 160 mm. of mercury before bladder drainage had been instituted. Of these, only two patients now have an abnormally elevated blood pres-

sure (one predrainage, 290-105; at present 260-110; the other predrainage, 240-100; at present 180-130), while the rest no longer have a blood pressure reading that can be considered above the normal limits for persons of their respective ages.

The blood pressure readings tabulated in the course of this study showed no association between the fall of blood pressure and the recumbency of the patient.

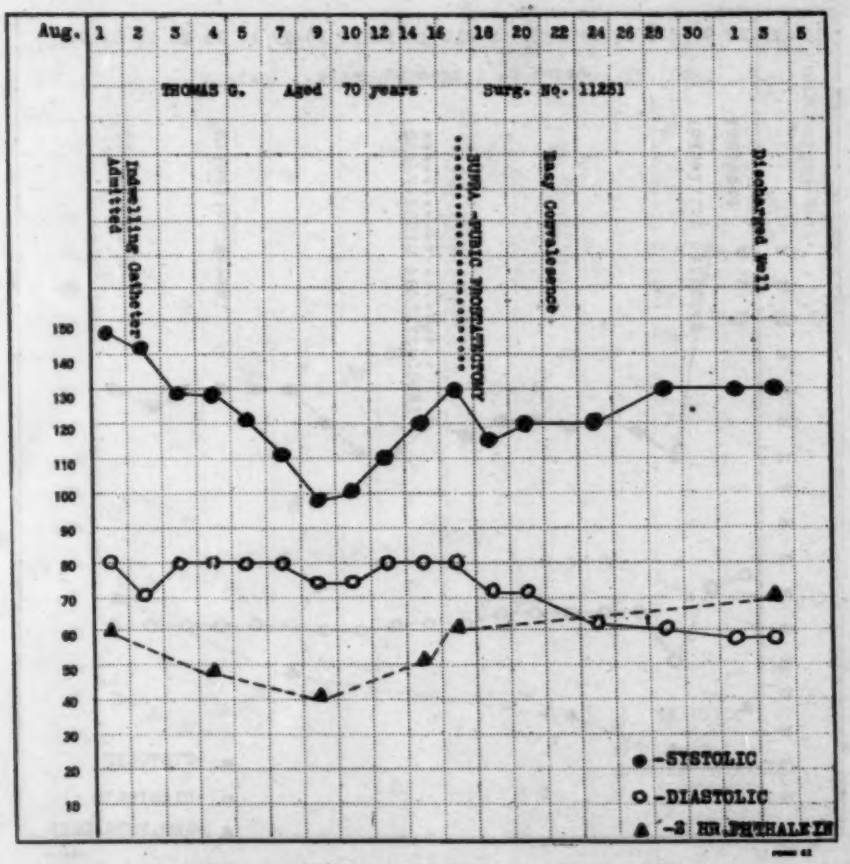

Chart 6.—Gradual fall on constant drainage with subsequent rise. No post-operative decrease in pulse pressure.

SUMMARY

1. Complete drainage of the bladder in patients suffering from urinary retention is attended by a marked fall in systolic blood pressure during the first forty-eight hours. During this period the renal function is diminished as shown by the phenolsulphonephthalein test and the quantitative determination of urea in the blood.

2. If satisfactory drainage of the bladder is continued, the blood pressure is gradually maintained at a definite, nonfluctuating level. During this period the adequacy of the renal function and the general condition of the patient indicate that he is in the best possible condition for operation.

3. Patients prepared for operation by waiting until this fixed blood pressure level has been established have shown a very insignificant postoperative decrease in blood pressure.

4. The majority of these patients who had suffered from long standing urinary retention, and who originally presented themselves with a hypertension, have continued thus far to be relieved of their abnormally high blood pressure except in a few instances in which demonstrable cardiac disease existed.

SURGICAL EXPERIENCES WITH AN INTRACRANIAL APPROACH TO CHIASMAL LESIONS*

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In May, 1914, an intracranial operation for exposing chiasmal lesions was devised and successfully performed on a patient with an hypophysial cyst. It was unlike the procedure of Krause, McArthur and the earlier operation of Frazier, in that it was an intradural rather than an extradural approach. It antedated the later operation of Frazier and the procedure of Adson—operations which, although differing in some details, are in principle the same. It has been consistently employed in lesions suitable for its use, first, because, at the time it was devised a serious trial of an intracranial approach had never been made, and second, because of the desire to learn whether such an approach offered more in the treatment of chiasmal lesions than does the popular nasal approach. Between 1914 and 1918, thirty-seven patients with chiasmal lesions have come to us for treatment. Six patients were not treated, either because operation did not seem indicated or because they refused operation. On two patients a simple decompressive craniotomy was performed for the relief of pressure symptoms; on five patients a transsphenoidal operation was performed, and on twenty-four patients the intracranial operation I shall subsequently describe was performed. On six of these patients a second intracranial operation was performed from one and a half to three years after the primary operation.[1] The series, then, is rather small; yet from a survey of the literature, it is the largest individual series in which an intracranial operation has been consistently used.

What knowledge have we gained by an intracranial exposure of the nature, the direction of growth, the clinical aspects and the accessibility of chiasmal lesions? How does this knowledge apply in determining what route—intracranial or transsphenoidal—to use in those who present symptoms and signs of a chiasmal lesion?

THE NATURE OF CHIASMAL LESIONS

The chiasmal lesions—using the term in a broad sense to indicate those tumors or cysts which arise in or about the optic chiasm—include the hypophysial tumors and cysts, the optic chiasm tumors

* Read before the Section on Surgery, General and Abdominal, at the Seventy-First Annual Session of the American Medical Association, New Orleans, April, 1920.

1. Of the thirty operations performed on these twenty-four patients, nine were performed by Dr. W. E. Dandy and twenty-one by myself.

and the suprasellar tumors and cysts. In our experience hypophysial lesions occurred in 73 per cent., suprasellar lesions in 24.3 per cent., and optic chiasm lesions in 2.7 per cent. of the cases.

These percentages probably more truly represent the proportion of these lesions than do those in the literature at present. Fully 90 per cent. of the cases in the literature are reported as hypophysial lesions; yet when we read the operative reports and the findings in necropsy examinations it is clear that many cases reported as hypophysial and in which operation was performed by the nasal route were suprasellar lesions. This point is of considerable importance; it indicates the difficulty that has been experienced in differentiating between hypophysial and suprasellar lesions; and it suggests that surgeons have heretofore been attacking indiscriminately by one approach all lesions about the chiasm.

Pathologically, the lesions in our series were made the subject of a special study by Duffy, the results of which are: Of the twenty true hypophysial lesions in which operation was performed, solid tumors occurred in 80 per cent., cystic tumors in 20 per cent. In 100 per cent. of the solid tumors the diagnosis of adenoma was made. In all of the cystic tumors, adenomatous tissue was demonstrable in the walls of the cysts. True cysts of the hypophysis therefore did not occur in this series. Of the seven suprasellar lesions in which operation was performed, three were solid tumors (gliomas of the anterior perforated space, or base of the brain), three were cysts arising from cell inclusions of the craniopharyngeal duct, and one a solid and cystic tumor (glioma) arising from the base. The one lesion of the optic chiasm in this series was a sarcoma arising from the nerve sheath. These findings emphasize what the more recent literature on the pathology of chiasmal lesions has indicated; namely, that with increasing knowledge more and more cases which were previously diagnosed as carcinoma, sarcoma, epithelioma, malignant adenoma, and endothelioma of the hypophysis are now recognized as adenomas, and that perhaps 50 per cent. of the suprasellar lesions are cysts arising from embryonic inclusions of the craniopharyngeal duct.

DIRECTION OF GROWTH

It is well known that in the early period of their growth hypophysial lesions are confined within the sella turcica. Sooner or later, however, they extend beyond the confines of the sella and their growth is either downward, toward or into the sphenoidal sinus, or upward into the intracranial chamber. It has been assumed, from the fact that at transsphenoidal operations the floor of the sella turcica has been found thinned or completely absent, that the direction of growth is primarily downward; and one of the arguments used in favor of

the transsphenoidal approach has been that it permits, by removal of the floor of the sella turcica, the downward growth of hypophysial lesions. It is indeed true that hypophysial lesions are found filling the sphenoidal sinus; but that their growth has been primarily in this direction, or that it has occurred to a greater extent in a downward rather than an upward direction seems to us incorrect. In my examina-

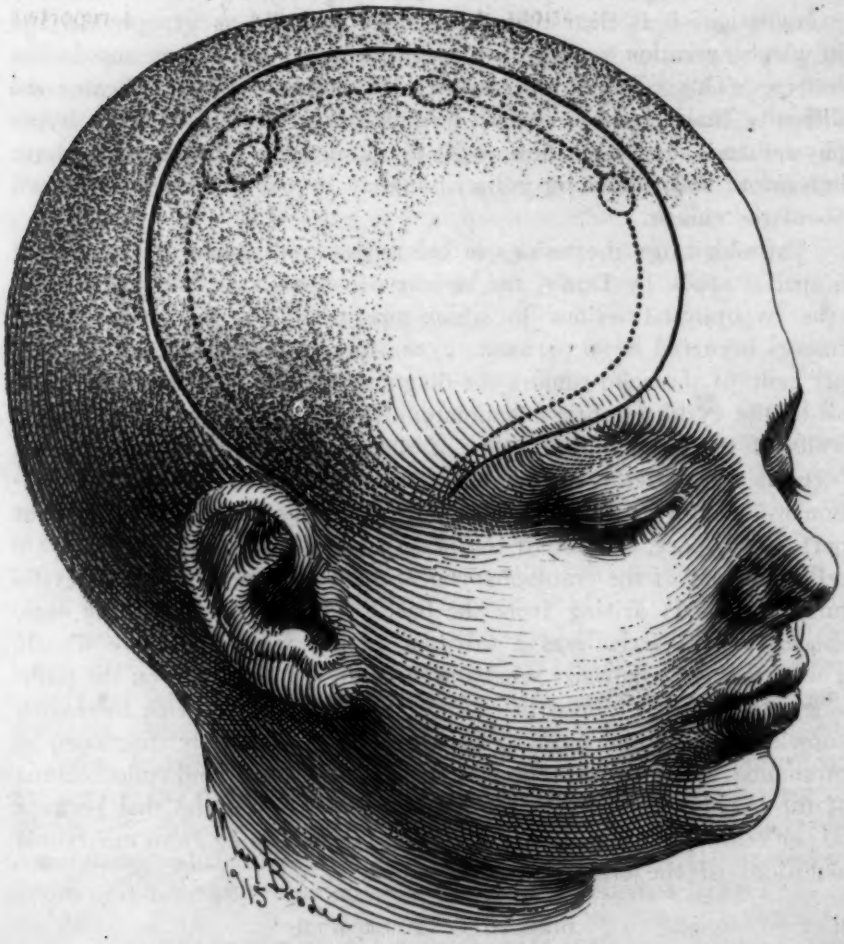

Fig. 1.—Outline of scalp and bone flap in the approach to the chiasmal region.

tion of reports in the literature of cases in which the patients died after transsphenoidal operations, I have found that in practically 100 per cent. of the cases—even though the floor of the sella turcica has been eroded and the tumor fills the sphenoidal cavity—a far larger proportion of the tumor has extended into the intracranial chamber. Moreover, our

personal experience in viewing hypophysial lesions through an intracranial approach has demonstrated two important points: First, that before the floor of the sella turcica has been eroded and even before the posterior clinoid processes have become destroyed, the hypophysial lesion has broken through the diaphragm of the sella turcica and become an intracranial growth; and second, that even though the floor of the sella turcica is removed by early operation conducted through the nose, the lesion will not, or only to a slight extent, grow downward, but will in spite of these measures grow upward into the intracranial chamber. It seems evident to us, therefore, that the diaphragma sellae offers the least resistance to the growth of hypophysial lesions and that their growth is primarily and always in greatest extent upward and into the intracranial chamber.

Their direction of growth after hypophysial lesions have broken through the diaphragma sellae has been the subject of investigation, and from an operative standpoint the determination of this point is of great importance. Obviously, hypophysial lesions may grow directly upward toward the base of the brain; they may grow forward, appearing in front of the optic chiasm and between the optic nerves; they may grow backward behind the chiasm and extend posteriorly in the cleft between the base of the temporal lobe and pons; and finally, they may grow laterally into the temporal fossae and involve the cavernous sinuses. From the literature, we gather that hypophysial tumors have been found at necropsy extending in all these directions; but owing to the incompleteness of the reports, and to the fact that postmortem examinations have been made chiefly in late cases, it cannot be determined in what special direction, if any, these lesions primarily grow. Cope, on anatomic grounds and from a study of the literature, concludes that the early intracranial extensions of hypophysial tumors are forward in front of the optic chiasm; and our personal experience is overwhelmingly in support of his findings. In twenty-two intracranial exposures of true hypophysial lesions the intracranial extension was forward—appearing in front of the optic chiasm and between the optic nerves—in twenty instances; and was forward and laterad in two instances. In four of the cases in which the lesion appeared forward, a second exposure made one to two years after the primary, again disclosed the lesion appearing forward. Extension backward did not occur in our moderately early cases. Our necropsy examinations confirm these operative findings. Moreover, the diagrams of Schloffer and the more recent diagrams of the operative findings in Adson's six cases, support our observations; and I believe it may be stated, therefore, that the early intracranial extensions of hypophysial lesions are forward and appear in front of the optic chiasm between the optic

nerves. From the point of view of operative procedure, the importance of this point is that the forward intracranial extensions of hypophysial lesions are readily accessible by intracranial operations.

The suprasellar and the chiasmal lesions need not be discussed from this standpoint. They are primarily intracranial tumors and can be satisfactorily approached only by an intracranial route.

CLINICAL ASPECTS OF CHIASMAL LESIONS

From a clinical point of view, cases which present symptoms of a chiasmal lesion may be roughly grouped as follows:

1. A group of cases which present evidence of disturbed hypophysial function either on the side of lessened activity (obesity, sexual abnormalities, drowsiness); on the side of increased activity (early acromegaly); or mixed types. There are no discomforts, such as headache; and there are no neighborhood symptoms (pressure on the chiasm). The sella turcica may be normal in size, it may be small or it may be enlarged. It does not show any destruction. Up to the present time, surgery in this group of cases has not been considered indicated.

2. A group of cases with glandular symptoms (acromegaly or mixed glandular symptoms) and with pronounced sellar headaches. There may be slight visual disturbances, as evidenced by contraction of the visual fields, but no hemianopia. The sella may be enlarged but shows no evidence of destruction nor alteration in the distance relations between anterior and posterior clinoid processes. It has been assumed that the struma, if such it be, is confined to the sella turcica and has not invaded the intracranial space. Surgery may attempt in this group to relieve the headaches. Whether it should attempt more, such as the removal of a part of the gland, has seemed doubtful.

3. A group of cases with pronounced "neighborhood" symptoms (various forms and degrees of hemianopia, optic atrophy, diminished visual acuity, ocular palsies). There may be evident glandular symptoms of the acromegalic, Froelich, or mixed types; or glandular symptoms may be absent. The sella turcica is enlarged and has undergone varying grades of destruction. This group of cases has been considered most favorable for surgery, and operative procedures—in the vast majority of cases conducted through the nose—have been directed to relieving the neighborhood symptoms; only incidently to correcting secretory abnormalities.

4. A group of cases which in addition to the signs and symptoms just outlined (Group 3), present signs of increased intracranial tension (headache, vomiting, choked disk superimposed on atrophy). The

lesion originating in or about the sella has given rise to an intracranial extension sufficiently large to produce general pressure and sometimes focal symptoms. Surgery in this group has chiefly attempted to relieve general pressure symptoms for it has assumed that the primary lesion is inoperable.

The four groups of cases thus far considered represent successive stages in the growth of true hypophysial lesions.

5. A group of cases in which the lesion is primarily suprasellar in origin. The lesion arises either from cell inclusions of the craniopharyngeal duct or from the base of the brain and causes pressure on the chiasm and hypophysis from above. There may be the neighborhood symptoms described under Group 3 and glandular symptoms due to hypophysial deficiency. The sella turcica may be normal, enlarged, flattened, partly or completely destroyed. In the later stages, there are in addition general pressure symptoms due often to an internal hydrocephalus from occlusion of the third ventricle. Surgery in this group of cases has thus far been unsuccessful.

6. A group of cases—exceedingly small—in which the lesion arises from the optic chiasm itself. Only one such case has occurred in our series, and I have been unable to find records of similar cases. They may be grouped with the suprasellar lesions, both from the standpoint of symptomatology and treatment.

Let us discuss these clinical groups from the standpoint of our operative findings in order to discover to what extent the clinical signs we have relied on actually indicate the size and extent of the lesion. We have no data on the first group, for in the presence of secretory abnormalities alone and in the absence of headache or visual disturbances we have not felt justified in resorting to surgery. In the second group of cases, it has been assumed that the absence of visual disturbances and the absence of destruction of, or alteration in, the distance relations between the clinoid processes are indications that the hypophysial lesion is confined to the sella turcica. Such, however, is not the case. We have found by an intracranial exposure that in the total absence of visual disturbances and in the absence of destruction of, or alteration in, the distance relations between the clinoid processes, hypophysial tumors have broken through the diaphragma sellae and presented moderate and even large intracranial extensions. The intracranial extensions may even appear forward between the optic nerves. Such has been found to be the case, for example, in typical acromegalics presenting no symptoms or signs other than so-called sellar headaches. In the third group which clinically present "neighborhood" symptoms and enlargement and varying grades of destruction of the sella turcica, there has invariably been a large intracranial extension of the hypophysial growth; so large, indeed, as to make the nasal approach—almost invariably used in these cases—

seem utterly futile. In the fourth group the intracranial extension is again invariable and even larger than in the third group. In the fifth group, the lesion is primarily intracranial; but here the question of differential diagnosis between hypophysial and suprasellar lesions arises. Our experience confirms the previously recognized fact that in general the *early* suprasellar lesions give rise to visual disturbances before there is much alteration in size or shape of the sella turcica. Moreover, in three of our cases particles of bone in the walls of suprasellar cysts gave rise to shadows above the sella turcica. But in the later stages of these lesions, symptoms and signs exactly like those of hypophysial lesions are the rule; and in the presence of neighborhood symptoms, glandular symptoms, and varying grades of enlargement and destruction of the sella turcica, a differential diagnosis is indeed difficult. That it cannot with any certainty be made has been our experience; that it has often not been made by others is clearly indicated from a study of the necropsy records in the literature.

Exclusive of Group 1, in which surgery at the present time is not considered indicated, every patient therefore that presents symptoms of a chiasmal lesion has in all probability an intracranial growth. The only possible exceptions are the cases falling in Group 2, and in these, while we have not a sufficient number of cases to speak positively, we know that an intracranial growth may be present.

THE ACCESSIBILITY OF CHIASMAL LESIONS

With the exception of a few dissenting views, surgical opinion thus far has been overwhelmingly to the effect that chiasmal lesions cannot be successfully attacked by an intracranial approach. Of this opinion have been those who have in largest measure contributed to our knowledge of the clinical manifestations and surgical treatment of chiasmal lesions. Their views may be thus roughly summarized:

The transsphenoidal approach will always remain the operation of choice. The intracranial route is not feasible for tumors confined to the sella turcica. It can be only palliative in the majority of cases since it does not become the operation of choice until the tumor is far advanced and since it will be impossible to remove the part of the tumor lying in the sella turcica. It fails to cope successfully with suprasellar lesions.

Our experience is at variance with these views. From the standpoint of accessibility every chiasmal lesion excepting the portions of hypophysial tumors which have extended far behind the chiasm may be exposed by an intracranial route. Tumors entirely confined to the sella turcica (rare, as we have shown) or portions of tumors within the sella turcica are easily accessible when properly approached and are susceptible of removal. Tumors which have passed beyond the confines

Fig. 2.—Exposure of the chiasmal region. The frontal lobe has been elevated, the temporal lobe displaced posteriorly. The brain is protected by cotton. The right optic nerve has been brought into view and appearing in front of it and between the two optic nerves is a deep red cystic tumor. The anterior cerebral artery is seen crossing the proximal portion of the right optic nerve. (Drawn by Mr. Brödel at operation.)

Fig. 3.—Drawing showing the ease with which the sella turcica, *a*, may be entered after removing the anterior extension of a hypophysial tumor; *b*, optic chiasm.

of the sella are not only accessible but their size and their operability can be determined. Cysts of the hypophysis are readily accessible, for they, as the solid tumors, appear forward and are as readily susceptible of drainage or removal as by the transsphenoidal approach. Supra-sellar lesions are accessible, as are the true chiasmal lesions; tumors which cannot be approached by the nasal route. From the standpoint

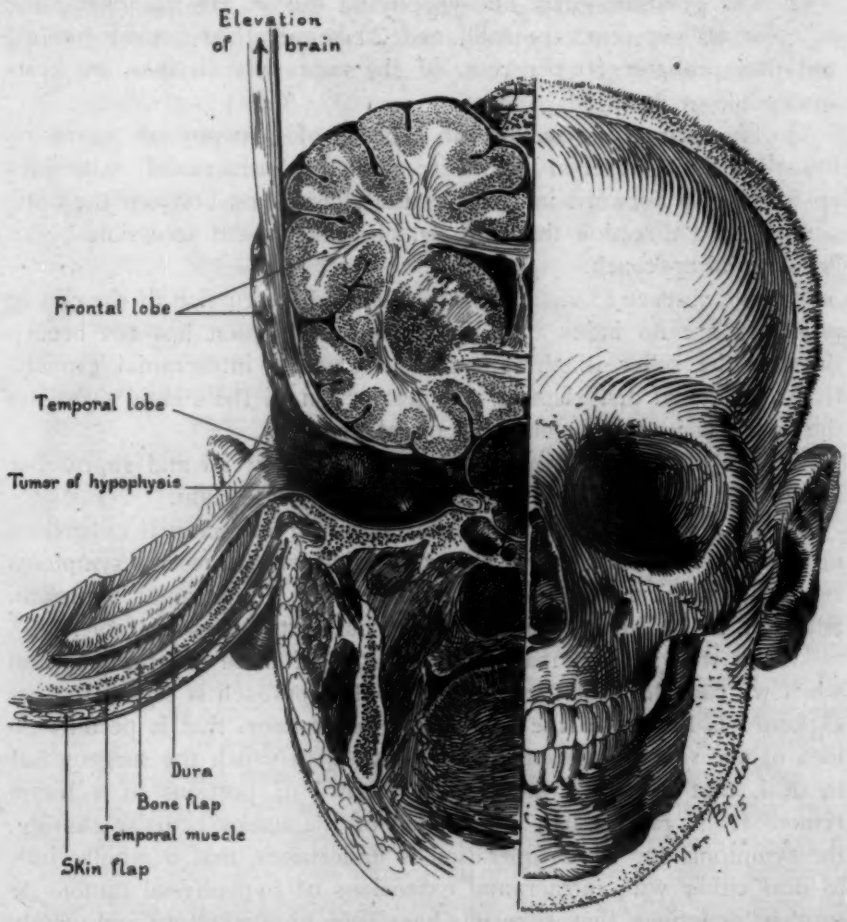

Fig. 4.—Semidiagrammatic sectional view of the approach to the chiasmal region. The approach is a lateral one, along the posterior border of the anterior fossa.

of accessibility, we would reverse the opinion of those just quoted and say that an intracranial approach best exposes and can most adequately deal with the greatest number of chiasmal lesions; and that the transsphenoidal approach should be considered only in those early cases—Group 2—in which there are sellar headaches but no neighborhood symptoms.

Our surgical experiences with an intracranial approach to chiasmal lesions have then been productive of the following observations:

1. The proportion of suprasellar lesions to hypophysial lesions is greater than the literature would indicate and that therefore a larger number of chiasmal lesions must be approached by an intracranial route.

2. The great majority of hypophysial lesions are adenomas, and of these 80 per cent. are solid and 20 per cent. are cystic tumors, and that probably 50 per cent. of the suprasellar lesions are cysts susceptible of drainage.

3. The primary direction of growth of hypophysial lesions is toward the intracranial chamber; and the intracranial extensions are primarilly forward in front of the chiasm and between the optic nerves—in a direction therefore which makes them accessible by an intracranial approach.

4. The absence of visual disturbances and destruction of the clinoid processes are no index that the hypophysial lesion has not broken through the sellar diaphragm and become an intracranial growth; that *with* visual disturbances and destruction of the clinoid processes the lesion is invariably an intracranial growth.

5. The differential diagnosis between hypophysial and suprasellar lesions at certain stages in their growth is very uncertain.

6. With the exception of the late posterior intracranial extensions of hypophysial lesions, every chiasmal lesion which presents symptoms requiring surgical relief is accessible by an intracranial approach, although, as I shall subsequently point out, not always operable.

When we view the matter in the light of these observations and when we consider that the transsphenoidal approach is septic, that its exposure is limited to the size of the sellar floor, that it permits no idea of the size and extent of the lesion with which the surgeon has to deal, that it merely allows the removal of portions of a lesion remote from, rather than the portion of the tumor actually causing, the symptoms for which operation is undertaken, that it wholly fails to deal either with intracranial extensions of hypophysial tumors or suprasellar lesions, that its results have been unsatisfactory and merely palliative, can we doubt that, at the present stage of chiasmal surgery, the intracranial approach to chiasmal lesions should have a wider trial? There are good reasons, however, why it should not at the present time be indiscriminately used, for, as the following pages will indicate, its mortality for the time being is high. It has been attended by certain complications, and its results are still none too brilliant.

OPERATION AND COMPLICATIONS

The operation which we have employed is adequately portrayed in the accompanying illustrations drawn by Mr. Brödel and requires

little description. An osteoplastic flap is turned down over the fronto-parietal region on the side presenting the greatest visual or other neighborhood symptoms. The flap should be large in order to permit more easily later cerebral dislocation. A dural flap is reflected concentric with the bone flap. Should the brain be under tension, a ventricular or lumbar puncture is performed before the base of the frontal lobe is elevated. The approach to the chiasm is neither a direct frontal nor a temporal, but midway between the two and along the posterior margin of the anterior fossa. It is the shortest approach to the chiasmal region. The posterior part of the base of the frontal lobe is elevated and the chiasm brought into view. The hypophysial lesion, if such it be, will immediately present itself. It has lifted the chiasm and come forward over the anterior margin of the sella turcica between the optic nerves. The extent of the growth and its relations to the internal carotid arteries can readily be determined. The portions of the lesion that appear, be they solid tumor or cyst, are removed, after which the sella turcica can be entered through the space between the uplifted chiasm and the anterior border of the sella. In the presence of suprasellar lesions a different picture presents itself. The optic chiasm is depressed, not elevated as in chiasmal lesions. The part of the lesion that appears is behind the chiasm, yet if it is a cyst it can be successfully attacked. In the large lesions, the downward extension may actually be seen occupying the sella turcica.

This operation has up to the present time been performed largely on patients in the late stages of chiasmal tumors. The lesions have with few exceptions been large. Our attitude toward them has been deliberately radical, and, excepting the solid suprasellar lesions which we have found thus far impossible to remove completely, we have attempted the removal of every lesion which presented itself, regardless of its size. In every case of hypophysial lesion, we have entered the sella turcica and removed partly or wholly its intrasellar portion.

The complications which we have encountered at the time of operation are these: Sufficient elevation of the brain to deal successfully with the lesion has been impossible in the case of solid suprasellar tumors only. In the course of elevation, the cortex has, of course, been compressed, but not lacerated, due to careful protection and the use of broad spatulas. As a result of this elevation the olfactory nerve has been torn out of the cribriform plate on the side of operation in two instances. Unintentional laceration of one optic nerve has occurred in one case during the attempt to remove a large hypophysial tumor. The internal carotid artery infiltrated and surrounded by tumor tissue was once completely torn across flush with its point of entrance into the intracranial chamber. The hemorrhage was successfully controlled, but only after ligation of the internal carotid in the neck. Injury to the anterior cerebral artery occurred in two instances, but in each the vessel was successfully ligated.

The postoperative complications, aside from those due presumably to hypophysial deficiency, have been largely the result of elevation of the brain. Convulsions occurring within forty-eight hours after operation occurred in three cases; twitching of the muscles of the face and hand occurred in three additional cases. Weakness of the face alone or the face and arm occurred in three cases. Speech defects occurred in two cases. These complications in those who recovered from the operation were but temporary and had disappeared usually by the end of the first week. Cerebral edema giving rise to general pressure symptoms occurred in two cases and was the primary cause of death. A sharp temperature reaction, the temperature sometimes rising to from 105 to 106 F., has been common.

Symptoms of disturbed hypophysial function have been present as follows: A stuporous lethargic condition has been present in six cases; excessive thirst in three cases; marked polyuria and polydipsia in four cases; excessive hunger in two cases. A few of our deaths, as we shall point out, occurred in patients showing signs of hypophysial deficiency, and it is possible that our extirpations have been too radical.

RESULTS

Six patients, as previously noted, were not treated. They were either the very early cases included in Group 1, stationary acromegalics in whom operation did not seem indicated, or patients that refused operation. Two patients were treated by decompression for the relief of pressure symptoms. Five patients were subjected to a transsphenoidal operation, and all recovered. It is in the cases in which an intracranial operation was performed that we wish especially to study the results. Thirty intracranial operations with partial or complete removal of solid tumors or with evacuation of cysts were carried out on twenty-four patients. In six of these patients, therefore, a second operation was performed from one to three years after the first. The primary mortality was 37 per cent.; the total mortality from additional deaths due to second operations performed from one to three years after the primary operation was 46 per cent. When we examine into the causes of death we find: Eight of the deaths occurred within twelve hours after operation, and in these death must be ascribed directly to the operation. In three of these cases, death was due presumably to shock; in two cases it was preceded by signs of a rapidly on-coming cerebral edema. In three cases, the patients recovered consciousness and for a time were in good condition, with a not unusually rapid pulse and normal respirations. Within a few hours, however, the temperature rapidly rose to from 104 to 107 F., the pulse became rapid, the respirations increased in frequency but later decreased to as low as six per minute, stupor and unconsciousness appeared, and in this condition the patients died. Of the remaining six deaths, one

occurred on the fourth day after operation due to a repeatedly forming extradural clot; two patients died suddenly—one thirteen days after operation following straining at stool, the other fourteen days after operation, from pulmonary and cerebral embolism (confirmed at necropsy); two patients died five days after operation with all the

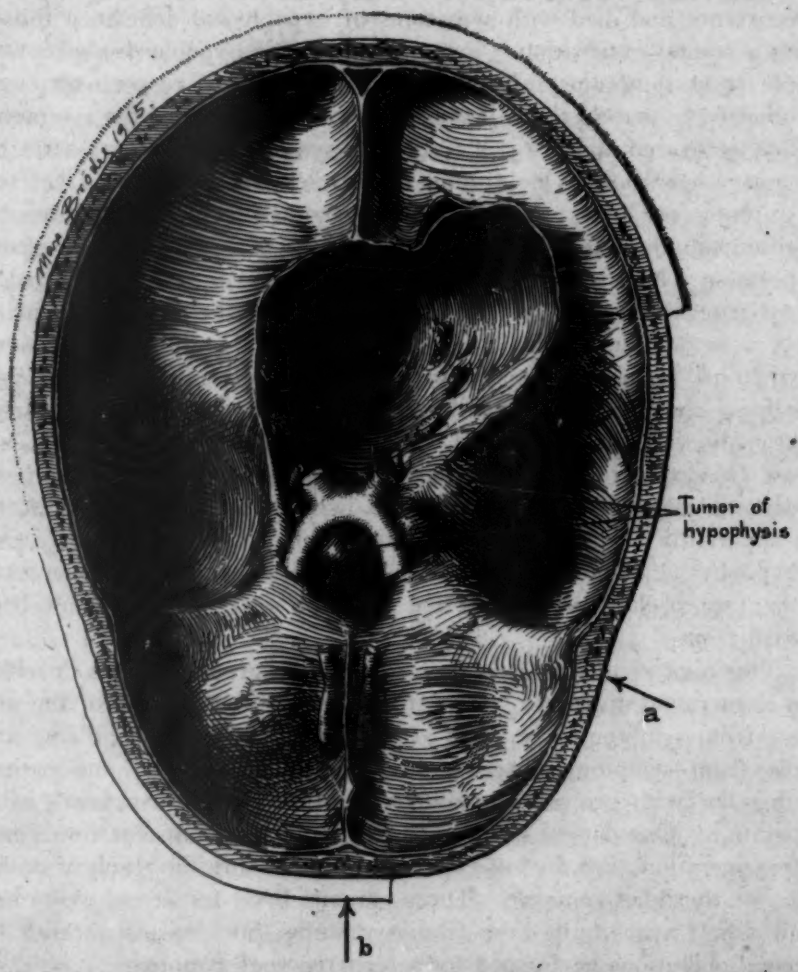

Fig. 5.—Drawing from a necropsy specimen showing the common anterior extension of a hypophysial tumor and also a lateral extradural extension of the growth into the temporal fossa. The approach is in the direction of the arrow at *a*. The lateral extension of the tumor in this case was accessible.

signs of hypophysial deficiency, and one patient died forty-six days after operation from internal hydrocephalus unrelieved by operation or by repeated ventricular puncture.

Of the patients who survived the primary operation, six were subjected to a second operation for a recurrence of the symptoms. One

(suprasellar cyst) had recovered her vision and was entirely free from symptoms for one and a half years; then died following the second evacuation of the cyst. One (hypophysial cyst) was free from symptoms for seven months, then had a recurrence of symptoms and died following the second evacuation of the cyst. One (adenoma of hypophysis) was free from symptoms for one year; then had a recurrence and died with symptoms of hypophysial deficiency following a second extirpation. Two (adenomas of hypophysis) who were free from symptoms for two years and one year, respectively, were subjected to second operations because of recurrence of the symptoms. Both recovered and are still free from symptoms, five years after the primary operation. One (tumor of optic chiasm) who was free from symptoms for four years, developed general pressure symptoms, due presumably to an internal hydrocephalus, and was subjected to a second operation which terminated in a decompression. This patient recovered from the second operation but has recently died. Of the remaining cases, one (suprasellar solid tumor), admitted with marked pressure symptoms for which a decompression was performed six years ago, is living and is absolutely without symptoms five years after a partial extirpation of the growth. One (hypophysial adenoma) is entirely free from symptoms three years after operation. One (hypophysial adenoma), operated on two years ago, is living but from a recent letter is apparently beginning to have a recurrence of the symptoms. One (hypophysial adenoma) died at her home four months after operation. One (suprasellar cyst), operated on four years ago, has not been heard from.

Our total results to date, therefore, in the group of cases in which an intracranial operation was performed, are three patients living and free from symptoms five years after operation, one patient living and free from symptoms three years after operation, and one patient living but with probably a recurrence of symptoms two years after operation. One patient lived quite free from symptoms for four years after operation, then died of internal hydrocephalus, the result of occlusion of the third ventricle. Three patients lived for from one to one and a half years quite free from symptoms, but died as a result of second operations performed for a recurrence of symptoms.

COMMENT

In view of what was attempted and actually done, it would be unfair to compare our mortality with that of the transsphenoidal operation. When we review the cases in which an intracranial operation was performed, we find that the large majority were late cases in which, in addition to the local symptoms of chiasmal disease, general pressure symptoms were present. A number of these patients had had transsphenoidal operations performed by other surgeons and came to us

for a recurrence of symptoms. In other words, our efforts were directed toward relieving those who were beyond help from the point of view of transsphenoidal operations, and in whom a simple decompression for the relief of pressure symptoms had been heretofore thought to be the only possible means of relief. Viewed from this standpoint our results are not quite so insignificant as would at first appear.

We may thus summarize our experiences in regard to the operability of chiasmal lesions: Chiasmal lesions are quite accessible by an intracranial approach. The cystic tumors whether hypophysial or suprasellar are, however, prone to recur, and we have not as yet been able by an intracranial approach to prevent their recurrence. The solid hypophysial tumors, excepting the rare posterior extensions, may be removed; when large, their removal has been attended by a high mortality, when small by a much lower mortality. The true lesions of the optic chiasm are so few that they need not seriously be considered. Yet they are capable of removal, and in our single case the patient lived for four years quite free from symptoms. The suprasellar solid tumors have thus far in our experience been impossible to remove completely; yet in one instance by a partial removal, we cured an internal hydrocephalus causing marked pressure symptoms, and the patient is still living and free from symptoms five years after operation.

As to the choice of operative procedures in patients who present signs of chiasmal lesion, we would suggest that both the transsphenoidal operation and an intracranial operation such as we have used have a field of usefulness. In the early cases which present sellar headaches and evidences of secretory derangement but without visual disturbances or destruction of the clinoid processes of the sella turcica, a transsphenoidal operation may well meet the requirements. A certain number of these patients may remain well for long periods; a fairly large number will sooner or later develop an intracranial extension of the growth, causing visual disturbances and destruction of the clinoid processes. Just as soon as these signs appear, the transsphenoidal approach will fail to deal adequately with the lesion; and rather than repeat this procedure it would appear wise to resort to an intracranial operation. For all other chiasmal lesions which at the time first observed are associated with visual disturbances and alterations in the shape and size of the sella turcica, the intracranial operation is the operation of choice; for in these we know that an intracranial tumor is present. It is true that our mortality following this operation is at present high; but we have reason to believe that if this operation is performed before the intracranial growths are too large, the mortality will be greatly lowered.

THE RESULTS OF OPERATIONS FOR INGUINAL HERNIA

PERFORMED IN THE JOHNS HOPKINS HOSPITAL FROM JAN. 1, 1899, TO JAN. 1, 1918

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At a meeting of the Johns Hopkins Medical Society held on Nov. 4, 1889, Dr. Halsted showed five patients operated on for inguinal hernia by a new method.[1] Dr. Halsted published several papers describing the operation during the first decade after the opening of the hospital, and in 1899, Dr. Bloodgood[2] published a voluminous monograph, the results of a comparative study of the operations performed in 459 cases of hernia in the Johns Hopkins Hospital from June, 1889, to January, 1899. During the period of the draft board examinations, an unusually large number of men were operated on for hernia, both in the civil hospitals and in the various camps, and it seemed most opportune to study anew the material available in the records of the hospital, giving especial attention to the operations performed since the publication of Dr. Bloodgood's monograph.

Bloodgood's study includes a report of all the cases of hernia in which operation was performed in the hospital from its opening in 1889 to the end of 1898, a period of nine and one-half years, and is a complete report of a large series of early cases in which the modern operation was performed. The conclusions drawn largely influenced the development of the present day operation. He traces the development of the operation from Dr. Halsted's first report in December, 1889, to the end of 1898. He calls attention to the fact that Bassini's[3] paper appeared several months subsequent to Dr. Halsted's report, in which the subjoined outline is given.

1. The incision begins at the external abdominal ring and ends one inch or less to the inner side of the anterior superior spine of the ilium on an

1. Halsted, W. S.: Radical Cure of Hernia, Bull. Johns Hopkins Hosp. **1**:12, 1889.

2. Bloodgood, J. C.: Operations on 459 Cases of Hernia in the Johns Hopkins Hospital from June, 1889, to January, 1899. The Special Consideration of 268 Cases Operated on by the Halsted Method, and the Transplantation of the Rectus Muscle in Certain Cases of Inguinal Hernia in which the Conjoined Tendon is Obliterated, Johns Hopkins Hosp. Rep. **7**:223-563, 1899.

3. Bassini, E.: Ueber die Behandlung des Leistenbruches, Arch. f. klin. Chir. **40**:229-276, 1890.

imaginary line connecting the superior spines of the ilia. Throughout the entire length of the incision everything superficial to the peritoneum is cut through.

2. The vas deferens, with its vessels, is carefully isolated up to the outer termination of the incision and held aside.

3. The sac is opened and dissected from the tissues which envelop it.

4. The abdominal cavity is closed by mattress sutures passed through the peritoneum at a higher level by 1⅛ inches than that of the so-called neck of the sac.[4]

5. The vas deferens and its vessels are transplanted to the upper outer angle of the wound.

6. Interrupted, strong silk sutures, passed so as to include everything between the skin and the peritoneum, are used to close the deeper portion of the wound, which is sewed from the crest of the pubes to the upper angle of the incision. The cord now lies superficial to these structures, and emerges through the abdominal muscles about 1 inch to the inner side of the anterior superior spine of the ilium.

7. The skin is united over the cord by interrupted stitches of very fine silk. The stitches do not perforate the skin, and when tied they become buried. They are taken from the under side of the skin, and are made to include only its deeper layers—the layers which are not occupied by the sebaceous follicles.

The first step in the modification of the operation was described by Dr. Halsted[5] when he published accounts of several cases in which operation was performed by the modified method. He described the excision of a number of the large veins of the cord by which its size could be reduced to about one fourth of the normal. This was done with the object of lessening the tendency of the hernia to recur along the path of the cord.

The following year, Dr. Halsted[6] published an important article in which he fully described the operation and reported eighty-two cases. The next year he[7] reported on the substitution of silver wire for silk in the closure. This was because of the frequency of infection in the early years following the use of silk material in this operation. The incidence of infection after the substitution of silver for silk became less. The wearing of gloves quite invariably for all operations by the operator as well as by the assistants was not insisted

4. In the light of the importance of the high ligation of the neck of the sac we are now better able to appreciate the value of this feature of the operation.

5. Halsted, W. S.: Excision of Some of the Veins of the Cord in the Operation for the Radical Cure of Inguinal Hernia, Bull. Johns Hopkins Hosp. **3**:76, 1892.

6. Halsted, W. S.: The Radical Cure of Inguinal Hernia in the Male, Bull. Johns Hopkins Hosp. **4**:17-24, 1893; Ann. Surg. **17**:542-556, 1893.

7. Halsted, W. S.: Report of Twelve Cases of Complete Radical Cure of Hernia by Halsted's Method of Over Two Years' Standing: Silver Wire Sutures, Bull. Johns Hopkins Hosp. **5**:98-99, 1894.

on until about 1896, although their use, begun in 1890, became increasingly common in the intervening years.

The percentage of infection being markedly reduced (1.8 per cent.) by the systematic wearing of gloves, it was found that silver wire could be discarded and silk again employed.

In 1895, Dr. Halsted [8] called attention to the occurrence of atrophy of the testicle following excision of the veins, and cautioned against the indiscriminate employment of this procedure. In 1901, and indeed in his first paper, he reported performing the operation without the transplantation of the cord, and in August, 1903,[9] he published the account of the use of the cremaster muscle [10] drawn under

8. Halsted, W. S.: Discussion upon Hernia, Tr. Am. Surg. **13**:343-344, 1895.

9. Halsted, W. S.: The Cure of the More Difficult as Well as the Simpler Inguinal Ruptures, Bull. Johns Hopkins Hosp. **14**: 208-214, 1903.

10. "The Use of the Cremaster Muscle. A device which we hit upon in our efforts to close more securely the lower part of the canal, but which we now make use of as often as feasible, probably in over 75 per cent. of the cases, is the utilization of at least a part of the cremaster muscle, which we formerly cut away. This is a step of the operation to which one is irresistibly drawn in some cases by the great strength of the cremaster and the firmness and extent of its attachments to Poupart's ligament. A natural insertion, such as this, of the cremaster and its fascia into Poupart's ligament, has in each case a value which can be demonstrated on the operating table and can be counted upon definitely to contribute something, and occasionally perhaps a great deal, to the strength of the abdominal wall; whereas the artificial insertion of the internal oblique into Poupart's ligament, although undoubtedly of the utmost importance and always to be tried for, may occasionally and perhaps often fail, from insufficient muscle, too great tension, or gradual redressment, to close securely even the upper part of the canal. The lower part of the canal, ordinarily protected by the conjoined tendon, can rarely be entirely safeguarded by the muscle fibers of the internal oblique when its conjoined tendon is deficient. The cremaster, on the other hand, seems in just these cases to serve a particularly good purpose. The cremaster, unaided, has repeatedly made such a complete and strong looking closure that we have felt the hernia would be well cured if the operation were abandoned at this stage.

"I have today, June 10, 1903, examined a patient whose very wide inguinal canals (the gap would have admitted the hand) were closed eighteen months ago solely by the cremasters stitched over instead of under the internal oblique muscle; the result, in the opinion of those who examined the case, is absolutely perfect, on both sides. My house surgeon, Dr. Follis, and one or two others examined the man with me. Even had I known what the result of this case was to be, I would have used, if possible, the internal oblique muscles in the old way, and hence have stitched the cremaster under rather than over the former. But the muscles were attenuated and not close at hand. Stitching the cremaster over the internal oblique muscle necessarily precludes the sewing of the latter to Poupart's ligament. The closure with the cremaster seems almost ideal in some cases—it is a method so inviting during the operation, and so true when finished, to one of the *great principles of surgery; there is no tension.* It is, in this respect, as a plastic operation should be.

the internal oblique, which constitutes an important step in the usual present day operation which I shall describe herewith in detail.

In the study of the ultimate results, Bloodgood was impressed with two causes for the recurrence of the hernia; the obliteration of the conjoined tendon as the cause of the recurrence in the lower angle of the wound, and the presence of the cord in the upper angle of the wound in those cases in which it had been transplanted intact without excision of the veins.

A summary of Dr. Bloodgood's monograph as given by Dr. Halsted [9] is reproduced in Tables 1, 2 and 3.

In the female, there were thirty-nine cases, with one recurrence through a rent in the aponeurosis.

In six patients operated on by the McBurney method, there were three recurrences.

Bloodgood made these observations concerning hydrocele: Hydrocele occurred in about 4 per cent. of the cases in which the veins had not been excised, and in 22 per cent. in which they had been.

THE PRESENT INVESTIGATION

The chief purposes of this investigation have been: (1) to determine the cause of recurrence or weakness in the wound following the various procedures made use of in the efforts to cure hernia, and (2) to appraise the value to be attached to each of the several features of the operation.

It must be evident that our objects would at the outset have been defeated had we not resolved to conquer the temptation to make the results appear as creditable as possible. The natural tendency to dim

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What the ultimate verdict will be it is too soon to predict. The cremaster fibers, particularly the hypertrophied ones, will, in time, atrophy; but when this occurs, the cremasteric fascia, perhaps stronger than before, would probably remain, holding together the atrophied muscle bundles. There can, at least, no harm result from this attempt to strengthen the wall, for the internal oblique muscle has been used in the usual manner. The worst that could happen would be a recurrence, in a certain class of cases at the lower angle, one that might, possibly, have been avoided if the aponeurosis over the rectus had been employed instead of the cremaster as described by the author. The future will decide these nicer points, and it would seem that only the nicer points remain now to interest the operator."

Dr. Halsted tells me he has just discovered the fact that he was not the first to recognize the value of the cremaster muscle in the operation for the cure of hernia. Alexander Brenner advised suturing the lower edge of the split cremaster muscle to the edge of the internal oblique in 1898 (Zentralbl. f. Chir. **25**:1017, 1898); Noetzel (Zentralbl. Chir. **45**:352, 1918) regrets the fact that Brenner's modification of the Bassini operation is practically unknown, and strongly recommends it.

the light on the first evidences of a possible recurrence may mislead the students and for a time the patient; but it may blind also the surgeon to the defects of his work and thus interrupt or bar his further progress.

TABLE 1.—SUMMARY OF THE ULTIMATE RESULTS, COMPLETE TO JUNE 1, 1899*

	Cases	Recurrences	Per Cent.
All cases Group 1 to 5 healing p. p.	301	13	4.3
All cases Group 1 suppurating	31	9	29.0
Total	332	22	6.6
Halsted's operation, Group 1, healing p. p.	218	9	4.1
Halsted's operation, Group 1, suppurating	20	6	30.0
Total, Group 1	238	15	6.2

* Recent cases, less than six months, and cases lost track of were not included.

TABLE 2.—RECURRENCES IN WOUNDS HEALING PER PRIMAM

	Cases	Recurrences
(1) At the position of the transplanted cord, veins excised	109	None
(2) At the position of the transplanted cord, veins not excised	109	7 (6.4%)
(3) Upper angle of the wound, cord excised, or not transplanted	83	1 (1.2%)
(4) Lower angle of the wound, conjoined tendon wide and firm, rectus muscle not transplanted	264	None
(5) Lower angle of the wound, conjoined tendon obliterated, rectus muscle not transplanted	8	5 (62.0%)
(6) Lower angle of the wound, conjoined tendon obliterated, rectus muscle transplanted	14	None
(7) Lower angle of the wound, conjoined tendon wide and firm, rectus muscle transplanted	16	None

TABLE 3.—RECURRENCE IN WOUNDS HEALING AFTER SUPPURATION

	Cases	Recurrences
(1) At the position of the transplanted cord, veins excised	9	None
(2) At the position of the transplanted cord, veins not excised	11	4 (36.3%)
(3) Upper angle of the wound, cord excised or not transplanted	11	1 (9.0%)
(4) Lower angle of the wound, conjoined tendon wide and firm, rectus muscle not transplanted	27	2 (7.4%)
(5) Lower angle of the wound, conjoined tendon obliterated, rectus muscle not transplanted	4	2 (50.0%)

From Jan. 1, 1889, to January, 1918, there were performed in the Johns Hopkins Hospital 256 operations for *direct* and 2,230 for *indirect* inguinal hernia. In July, 1918, letters were sent to all patients treated between these dates with the request that they present themselves for examination if possible, and if unable to do so, to send a report of the local condition from their physician. The results in 910 cases have been ascertained.

Of 816 cases of indirect hernia, the results are known in 356 from examination in this hospital, and of 460 cases we have reports from physician or patient. In the group (356) examined here, thirty

recurrences were found. Of the 460 patients who responded by letter, only sixteen reported recurrence. Evidently the patients overlooked early recurrences. As the percentage of recurrence in those examined by surgeons at the Johns Hopkins Hospital is more than twice as great as in those who reported by letter, we may conclude that recurrences have been overlooked by the patients themselves or their examining physicians, and hence that the actual number of recurrences is greater than our figues indicate. The average time that had elapsed since operation in 770 cured cases was six years, and the average time after operation of forty-six recurrent cases was forty-two months.

TABLE 4.—INDIRECT HERNIA

Number of operations for indirect hernia		2,230	(80.7%)
Patients examined at Johns Hopkins Hosp'tal	356	recurrences 30	(8.4%)
Patients heard from	460	recurrences 16	(3.4%)
Total known results	816	recurrences 46	(5.6%)
Average age of patients at time of operation		39 years	
Average age of the 46 patients at time of recurrence		41 years	
Average time after operation of recurrence in the 46 cases		42 months	

TABLE 5.—RECURRENCES OF INDIRECT HERNIA—FIVE YEAR PERIODS

	Patients Examined or Heard From	Recurrences	Per Cent.
1899–1904	279	26	9.3
1904–1909	137	7	5.1
1909–1914	171	11	6.4
1914–1918	229	2	0.8

TABLE 6.—INDIRECT HERNIA—PATIENTS CURED

Time Elapsed Since Operation	Number of Patients	Time Elapsed Since Operation	Number of Patients
6 months	15	10 years	18
1 year	113	11 years	16
2 years	105	12 years	14
3 years	105	13 years	16
4 years	73	14 years	17
5 years	49	15 years	23
6 years	36	16 years	17
7 years	38	17 years	22
8 years	24	18 years	11
9 years	27		

Of the patients operated on for direct hernia, forty-seven were subsequently examined at this hospital and found to be cured, and thirty so reported themselves by letter. In these seventy-seven cases, the average time that had elapsed since operation was five years. By examination here, fourteen recurrences were found, and three patients reported a recurrence by letter. The average period of recurrence in these direct cases was eight and six-tenths months after operation.

In attempting to determine the factors involved in the recurrence of an inguinal rupture there have been considered the type of the hernia, the condition of the structures—especially of the conjoined tendon—the features of the operation, the healing of the wound, the age and sex of the patient, and the operator.

In the course of this study a number of patients operated on previous to 1899 were incidentally seen, and the results of these examinations have been recorded in Table 7.

Of the ninety-five cases in which the veins were excised, hydrocele is known to have occurred in nineteen (20 per cent.).

Of 721 cases in which the veins were not excised, hydrocele occurred in twenty-eight (3.8 per cent.). The correspondence of these figures with those of Dr. Bloodgood (22 per cent.-4 per cent.) is striking.

Local anesthesia was used in the indirect hernia operation fifty times—recurrence, six (12 per cent.). Infection followed the use of local anesthesia in one case (no recurrence); an infected suture in this case was removed one year after operation.

TABLE 7.—Examination of Patients Operated on Previous to 1899

Time Elapsed Since Operation	Number of Patients	Time Elapsed Since Operation	Number of Patients
19 years	10	24 years	6
20 years	11	25 years	6
21 years	6	26 years	1
22 years	4	27 years	2
23 years	3		

Infection of the wound occurred in eight cases—recurrences, two (25 per cent.).

Cases of indirect hernia with more or less completely obliterated conjoined tendon, forty-eight—recurrences, eighteen (37.5 per cent.). This is a greater percentage of recurrence than in those cases of the direct variety in which the conjoined tendon was not obliterated. In these forty-eight cases of weak or partially obliterated conjoined tendon, the cord was transplanted eight times—recurrences, two (25 per cent.). In one of these recurrent cases, the recurrence was found at the lower angle of the wound; in the other case, the patient was not seen subsequent to the operation, the recurrence was reported by letter and its exact situation is unknown.

The rectus muscle was transplanted in twenty-two cases—recurrences, nine (40.9 per cent.).

A flap from the rectus fascia was transplanted in thirteen cases—recurrences, none.

The cord was transplanted in nineteen cases—recurrences, 7 (36.8 per cent.). The recurrence was found at the site of the transplanted cord in three cases, at the lower angle of the wound in one, and in three the position of the recurrence is unknown.

The cord was split, the veins alone transplanted in forty-four cases—recurrences, 8 (18.1 per cent.). In six of these cases the recurrence was found at the site of the transplanted veins, and in two at the site, as well, of the untransplanted vas deferens. Thus the splitting of the cord does not seem to have reduced the percentage of recurrence but to have transferred the site of the recurrence.

TABLE 8.—INDIRECT HERNIA—RECURRENCES—RESULTS OF THE INDIVIDUAL OPERATOR

Operator	Patients Examined or Heard From	Recurrences	Per Cent.
A	7	2	28.5
B	62	15	24.1
C	28	1	3.5
D	57	1	1.7
E	23	0	0.0
F	66	2	3.0
G	78	6	7.6
H	11	2	18.1
I	59	1	1.6
J	60	2	3.3
K	27	1	3.7
L	70	2	2.8
M	57	4	7.0
N	22	0	0.0
O	41	1	2.4
P	36	1	2.7
Q	18	1	5.5
Miscellaneous	94	4	4.2
Total	816	46	5.6

TABLE 9.—OPERATIVE DETAILS OF THE FORTY-SIX RECURRENT CASES

Local anesthesia used	6
Infection	2
Cord transplanted	7
More or less completely obliterated conjoined tendon	18
Veins excised	13
Rectus muscle transplanted	9
Cremaster drawn under internal oblique	13
Cord split, veins alone transplanted	8
Recurrence at site of transplanted veins	6

The cord was excised in twenty-one cases—recurrences, none.

There was an undescended testicle with indirect hernia in nine cases—recurrence, 1 (11.1 per cent.). In the recurrent case the testicle had been replaced in the scrotum. In the other eight cases, castration had been performed in four instances, and the testicle had been replaced in the scrotum in four.

There was a strangulated indirect hernia in eleven cases (two drained)—recurrence in both of the drained cases. In the nine undrained cases—recurrence, none.

Of eighty-seven cases in which the veins were not excised, hydrocele occurred in two (2.2 per cent), whereas in the nine treated by excision of the veins it occurred in seven (77.7 per cent.).

Local anesthesia was used in operations for direct hernia eleven times—recurrences, two (18.1 per cent.).

TABLE 10.—Direct Hernia

Number of operations for direct hernia		256 (10. 2%)
Patients examined at Johns Hopkins Hospital	47	recurrences 14 (29. 7%)
Patients heard from	47	recurrences 3 (6. 3%)
Total known results	94	recurrences 17 (18.08%)
Average age of patients at time of operation		42 years
Average age of the 17 patients at time of recurrence		44 years
Average time after operation of recurrence in the 17 cases		8.6 months

TABLE 11.—Recurrences of Direct Hernia—Five Year Periods

	Patients Examined or Heard From	Recurrences	Per Cent.
1890–1904	16	4	25.0
1904–1909	16	2	12.5
1909–1913	35	8	22.8
1914–1918	27	3	11.1

TABLE 12.—Direct Hernia—Patients Cured

Time Elapsed Since Operations	No. of Patients
1 year	15
2 years	11
3 years	16
4 years	8
5 years	4
6 years	4
7 years	4
8 years	1
9 years	10
10 years	1
11 years	1
12 years	1
18 years	1

Infection occurred in four cases—recurrences, two (50 per cent.). In one of the recurrent cases local anesthesia was used.

Of direct hernia with more or less completely obliterated conjoined tendon there were nineteen cases—recurrences, six (31.5 per cent.). This is approximately the same percentage of recurrences as that found in the indirect variety with obliterated conjoined tendon. In these nineteen cases of weak or partially obliterated conjoined tendon, the

cord was transplanted nine times with three recurrences (33.3 per cent.). The recurrence was found at the inner angle of the wound in one instance, in two its site is unknown.

The rectus muscle was transplanted in twelve cases—recurrences, three (25 per cent.).

A flap from the rectus fascia was transplanted in three cases—recurrence in one (33.3 per cent.).

The cord was transplanted in twenty cases—recurrences, five (25 per cent.). The recurrence was found both at the site of the transplanted cord and at the inner angle of the wound in one case, in one at the inner angle of the wound, and in three the site of the recurrence cannot be determined from the reports sent by letter.

TABLE 13.—DIRECT HERNIA, RECURRENCES—RESULTS OF THE INDIVIDUAL OPERATOR

Operator	Patients Examined or Heard From	Recurrences	Per Cent.
A	1	0	0.0
B	1	1	100.0
C	8	3	37.5
D	8	2	25.0
E	2	0	0.0
F	5	0	0.0
G	12	2	16.6
H	0	0	0.0
I	7	0	0.0
J	10	3	30.0
K	5	1	20.0
L	6	2	33.3
M	8	1	12.5
N	4	1	25.0
O	2	0	0.0
P	7	0	0.0
Q	1	0	0.0
Miscellaneous	7	1	14.2
Total	94	17	18.08

The cord was split and the veins transplanted in three cases—recurrence, none.

The cord was excised in four cases—recurrence, none.

MORTALITY

In the 2,486 operations performed since 1899 there have been nineteen deaths in the hospital. Seven of these were due to strangulated hernia, four to pulmonary embolism, one to myocarditis, two to meningitis, four to pneumonia, one, in an infant aged 17 months, to status lymphaticus. The total mortality was 0.76 per cent. Excluding the deaths due to strangulated hernia, it was 0.48 per cent.

TECHNIC OF OPERATION

A brief outline of the development of the operation at Johns Hopkins Hospital has been given above. The operation almost invariably performed at present is the one described by Dr. Halsted and beautifully illustrated by Max Brödel in 1903. No modification has been made in it since the publication of this paper.

The skin incision begins as a rule from a point a finger's breadth medial to the anterior superior spine and runs obliquely downward to the external ring, ending at a point one finger's breadth lateral to the pubic spine. The fat and superficial fascia are incised and the aponeurosis of the external oblique muscle split in the line of its fibers. The two columns of the external ring are then dissected back and the conjoined tendon well exposed.

TABLE 14.—Operative Details of the Seventeen Recurrent Cases

Local anesthesia used	2
Infection (1 after local anesthesia)	2
Cord transplanted	5
More or less completely obliterated conjoined tendon	6
Veins excised	2
Rectus muscle transplanted	3
Flap from rectus fascia transplanted	1
Free transplant from fascia lata	2
Cremaster drawn under internal oblique	8

TABLE 15.—Complications Following the Nine Hundred and Ten Operations for Inguinal Hernia

	Cases	Per Cent.
Pain following operation, reported in	138	15.2
Enlarged or painful testicle, reported in	56	6.1
Loss of sexual power, veins not excised	5	0.5
Hydrocele, reported in	56	6.1
Varicocele, reported in	14	1.5
Atrophy of testicle, reported in	23	2.5
Infection in the 910 cases	12	1.2

The iliohypogastric nerve usually courses too high to be endangered; the ilioinguinal is isolated and may be held out of the way over a clamp on the upper cut edge of the aponeurosis.

The cremasteric muscle is then incised longitudinally. The sac is opened and carefully and cleanly isolated on a finger placed within it. Sharp dissection is preferred to the rubbing with gauze as thus less trauma is likely to be caused to the structures of the cord.

The sac is dissected up to the highest possible point, its contents having been reduced. The neck of the sac is twisted, transfixed and tied with silk, Size C. Having been again inspected from within, the sac is cut away quite close to the ligature about its neck; the stump usually retracts well behind the edge of the internal oblique muscle.

Hemostasis must be perfect. The ligatures are of very fine black silk, Size A or O.

The closure is accomplished by utilizing the cremasteric fascia and muscles in the following way: Mattress sutures of silk are passed from above downward through the conjoined tendon and the internal oblique muscle in such a way that the cremaster muscle and fascia are drawn, without any tension, up under the edge of the conjoined tendon and internal oblique muscle, the knots of the mattress sutures being tied on the outer face of the muscle and tendon (Fig. 1).

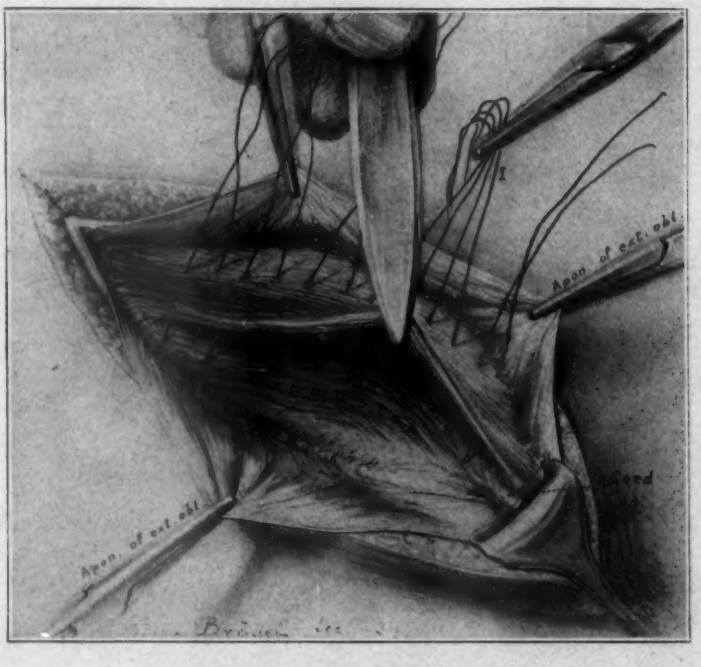

Fig. 1.—Use of the cremaster muscle. Drawing by Max Brödel.

The cord is not disturbed. The edges of the conjoined tendon and internal oblique muscle are then sutured to Poupart's ligament, if this can be done without tension, with interrupted sutures of black silk, the cord being closely embraced by these structures at the inner angle of the wound.

The flaps of the aponeurosis of the external oblique muscle are overlapped; the edge of the lower flap is tacked to the outer face of the conjoined tendon and the internal oblique and then the upper flap is brought down as an overlap and sutured at its edge to the underlying aponeurosis. The sutures throughout this procedure are interrupted and of fine black silk. The overlapped aponeurotic flaps also hug the cord quite snugly.

The superficial fascia and the skin are closed with interrupted sutures of fine silk. A small gauze dressing is held in place with a few straps of adhesive plaster. The patient is allowed to get up about the tenth day when the hernia is a simple indirect one, but may be kept in bed for three weeks in the more difficult cases of direct hernia.

In direct hernias the cord is sometimes transplanted, and if the conjoined tendon is thinned or narrow, a flap from the anterior sheath of the rectus is used after the manner described by Dr. Halsted [9] (Fig. 2). The illustrations are reproduced from Dr. Halsted's paper.

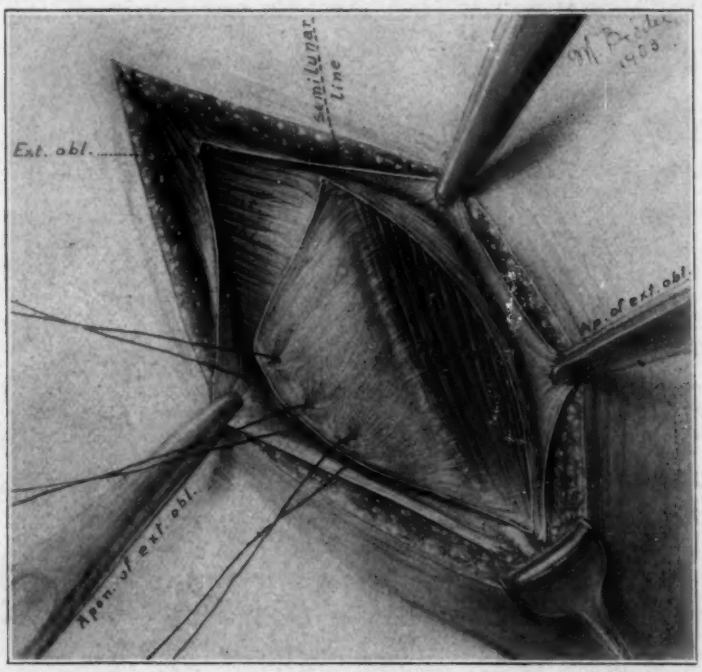

Fig. 2.—Transplantation of triangular flap from anterior sheath of rectus muscle. Drawing by Max Brödel.

REVIEW

The operation for uncomplicated hernia being a simple one, it is frequently entrusted to the younger members of the staff. We might expect that the higher percentage of recurrence would be found in the work of the relatively immature operators, but this proves not to be the case. The resident surgeons who have implicitly observed the details specified by Dr. Halsted have, as a rule, had the fewest recurrences, while Dr. Halsted himself has had slightly better results than any except those whose cases have been few, notwithstanding the fact that most of his patients were operated on many years ago.

We have examined or heard from sixty-six patients operated on by Dr. Halsted since 1899, seven with direct and fifty-nine with indirect hernia, and among these no recurrence has been found by us and only one reported. As the veins were excised in this case, recurrence is thought to be uncertain, particularly as it is not improbable that a hydrocele which developed while the patient was still in the hospital after the operation may have been mistaken for it.[11] His percentage of recurrence is therefore 1.5 or perhaps none.

Conclusions as to the relative value of the various details of the operation are difficult to draw from data furnished by so many operators and recorders. The histories as a rule were found to be creditably complete. In the ordinary indirect hernias, the best results have been obtained by those who performed the operation strictly as described above—cord untransplanted, cremaster sutured to the undersurface of the internal oblique muscle, flap of rectus sheath made use of when indicated.

TABLE 16.—DISPOSITION OF THE CORD

INDIRECT HERNIA				
Cord transplanted	19	recurrences	7	(36.8%)
Cord not transplanted	732	recurrences	31	(4.2%)
Cord excised	21	recurrences	0	
Cord split, veins alone transplanted	44	recurrences	8	(18.1%)
DIRECT HERNIA				
Cord transplanted	20	recurrences	5	(25 %)
Cord not transplanted	68	recurrences	12	(17.0%)
Cord excised	3	recurrences	0	
Cord split, veins alone transplanted	3	recurrences	0	

In both types of hernia, when the conjoined tendon was pronounced to be lacking, the percentage of recurrence is found to be exceedingly high (35.8);[12] the best results in such cases have been obtained when a flap of the sheath of the rectus muscle has been made use of. There has been only one recurrence in this little group of cases, notwithstanding the fact that this operative detail (transplantation of the rectus sheath) has been resorted to only when the conjoined tendon has been defective, and it has occasionally been practiced by operators who had not familiarized themselves with the proper method of employing it. The transplantation of the rectus muscle seems to have availed nothing. In the thirty-four cases in which it has been tested, there have been twelve recurrences (35.3 per cent.). Dr. Halsted has never advocated the employment of this feature, maintaining that

11. In several instances reported recurrences have proved to be hydroceles.

12. Dr. Bloodgood directed attention to this fact in his first paper and has emphasized it in recent publications.

TABLE 17.—Recurrences of Indirect Hernia

Surg. No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
8479 ♂, 33 G	Jan. 4, 1899. Ether. Conjoined tendon wide and firm. Muscles strong. Sac tied with silk. Cord transplanted intact. Rectus muscle not transplanted. Closure with silver. Healing per primam. No epididymitis.	Recurrence noticed in 5 months. Jan. 15, 1899, second operation, "G." Recurrence found between vas and veins. Veins excised. Silver sutures. Healing per primam. Second recurrence 5 years later at site of cord. New hernia on opposite side. Third operation, Jan. 3, 1906, "G." Silver removed, silk used. Cremaster found puckered between oblique and Poupart's. Ordinary operation not performed because of excessive scar tissue formation and obliteration of normal anatomic relations. Ultimate result unknown.
8485 ♂, 34 B	Jan. 5, 1899. Ether. Conjoined tendon obliterated. Tissues adherent from old inflammation. Sac closed high with silk. Cord transplanted intact. Rectus muscle sutured to Poupart's. Healing per primam.	July, 1918. Letter from patient, "Recurrence in about 4 months after operation." This patient has not been seen subsequent to operation.
8489 ♂, 18 B	Jan. 5, 1899. Ether. Conjoined tendon well developed. Internal oblique strong. No sac found. Cord transplanted intact. Silver sutures, the lowest one through rectus muscle near spine; sheath not opened. Healing per primam.	April, 1901. Letter from patient, "Time and money thrown away." July, 1918. Letter, "Conditions same as before operation. Wearing truss."
8525 ♂, 23 B	Jan. 23, 1899. Ether. Very large ring. Conjoined tendon strong. Sac very adherent to vein and cord and difficult to remove. Veins excised and cord transplanted. Bassini closure used. Hypospadias and undescended testicle on left where there was no hernia.	Recurrence in 2 years and 4 months. May 23, 1901, second operation, "L." Recurrence found at point of exit of vas. Divided internal oblique existed as a mass of scar tissue. Rectus muscle sutured to Poupart's over cord which was brought down close to pubic spine. Ultimate result unknown.
8548 ♂, 23 B	Jan. 21, 1899. Ether. Conjoined tendon and other structures strong. Sac ligated with purse string suture. Veins excised. Cord transplanted. Wound closed with 5 buried silver sutures, rectus included. No suture nearest symphysis. Cord transplanted so high that testicle was drawn slightly above its original level. Slight hydrocele followed.	May, 1901. Letter from patient, "Testicle three times its size—you can see that the hernia is coming down again." July, 1918. Letter, "Have worn a truss since operation. Swelling below cut, size of pigeon's egg."
8608 ♂, 23 B	Feb. 4, 1899. Ether. Conjoined tendon very narrow. Muscle fibers strong. Cord split, veins alone transplanted. Rectus muscle sutured over vas to Poupart's. Very vascular case. Healing per primam.	Recurrence in about 1 year at upper angle of wound, at site of transplanted veins, also slight recurrence at external ring, making an hour-glass sac. May 27, 1903, second operation, "F." Veins excised. Cremaster sutured under internal oblique. Position rectus muscle not stated. Operation difficult on account of scar tissue and disturbance anatomic relations. Small drain. July, 1918. Examination here showed perfect result.
8634 ♂, 23 Misc.	Feb. 6, 1899. Ether. Conjoined tendon strong and broad. Congenital type of sac. Lower part of sac ligated and left in scrotum. Cord transplanted. Lowest sutures included edge of rectus. Healing per primam.	July, 1918. Letter from patient's physician, "Recurrence at site of cord, one year after operation. New hernia on left."

* ♂ represents male.

TABLE 17.—RECURRENCES OF INDIRECT HERNIA—CONTINUED

Surg. No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
8663 ♂, 51 A	Feb. 21, 1899. Ether. Conjoined tendon strong. Veins excised. Cord not transplanted. Healing per primam. Slight swelling right cord and testicle, apparently due to small hydrocele, in 1 month.	Recurrence in 2 years and 8 months. Oct. 30, 1901, second operation, "B." Recurrence found as new hernia between rectus and deep epigastric, pushing conjoined tendon in front. Internal oblique had pulled away from Poupart's. Adherent to sac at its lower end was a large mass of edematous scar tissue, in the center of which, stump of ligated veins. These evidently were ligated too low at first operation. They were religated. Vas deferens ligated. Cord excised and rectus muscle transplanted. No subsequent report.
8865 ♂, 24 G	April 21, 1899. Ether. Conjoined tendon very strong. Internal oblique fair. Cord split and veins alone transplanted. Femoral ring large; extra silver suture to pucker and decrease this. Strong closure. Took anesthesia badly. Healing per primam.	Recurrence in 1¼ years. May 12, 1912, second operation, "J." Recurrence found at site of transplanted veins. These veins were excised and vas allowed to fall back behind the internal oblique close to the spine. Cremaster not definitely recognized. Has double varicocele. July, 1918. Letter from patient, "I am completely cured."
8866 ♂, 48 B	April 22, 1899. Ether. Very large irreducible hernia. Conjoined tendon narrow and weak. Internal oblique rather large and strong. Cord not transplanted. Closure satisfactory except at lowest angle where rectus muscle was sutured to Poupart's over cord. Silver mattress sutures. Infection after operation, lower half of wound widely opened.	Recurrence in about 4 months. Aug. 4, 1899, second operation, "B." Recurrence found at lowest angle of wound. Internal oblique and transplanted rectus not positively identified. Cord isolated and excised with testicle. Rectus muscle exposed and included in all except lowest sutures. Healing per primam. No subsequent report.
8894 ♂, 47 B	May 8, 1899. Ether. Double hernia. Conjoined tendons thin. Aponeurosis of external oblique thin; internal oblique and rectus strong, on both sides. Right side: cord split, veins alone transplanted. Rectus sutured to Poupart's over vas. Left side: no sac. Large bundle veins excised. Vas not disturbed. Closure as on right with transplantation of rectus and internal oblique. Hydrocele excised on left in March, 1902.	Recurrence on right side 2 years after operation; on left, 10 years. March, 1918. Examination by Dr. Halsted: Recurrence at each external ring, also small recurrence at site of new ring made by transplanted veins on right. On account of complications operation not advised (two recurrences).
9342 ♂, 21 B	Aug. 26, 1899. Cocain. Conjoined tendon not palpable. Other structures not described. Veins alone transplanted. Very satisfactory closure. Healing per primam.	Recurred in 18 years. September, 1918. Examination on admission to hospital. Definite recurrence above center of Poupart's 2½ by 4 cm. in size, at site of transplanted veins. Refused operation and was discharged at his own request.
9396 ♂, 42 B	Sept. 12, 1899. Ether. Conjoined tendon not felt. Pillars strong. Internal oblique strong. Veins very large, not excised. Cord not transplanted. Rectus muscle sutured to Poupart's over cord. Closure satisfactory. Healing per primam.	January, 1900. Examination. Recurrence at lower angle of wound. No subsequent report.
9447 ♂, 53 B	Sept. 26, 1899. Cocain. Conjoined tendon obliterated. Muscle fibers thin. Neck of sac very large, closure with difficulty. Veins very large, excised. Vas not transplanted. Rectus muscle sutured to Poupart's over vas. Hernia of sliding variety. Hydrocele occurred within a month. Excised.	Recurrence in 2 years after operation. March, 1902. Examination: hernia now size of a large egg. Operation advised (no note as to its site). No subsequent report.

* ♂ represents male.

TABLE 17.—Recurrences of Indirect Hernia—Continued

Surg. No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
9928 ♂, 37 B	Jan. 25, 1900. Ether. Conjoined tendon very weak. Hernia size of ostrich egg. Veins excised. Vas transplanted. Rectus sutured to Poupart's Silver sutures. Healing per primam. Large hematoma formed in wound.	Recurred in about 5 years. Jan. 11, 1905, second operation, "I." Recurrence found at lower angle of wound. Muscles and conjoined tendon weak. Anterior sheath of rectus reinforced this inner portion of wound; flap being turned down and sutured beneath Poupart's, after tissue corresponding to cremaster had been sutured beneath edge of internal oblique—in front of vas and its remaining vessels. No subsequent report.
9948 ♂, 20 I	Feb. 3, 1900. Ether. Conjoined tendon rather weak. Veins excised. Vas not disturbed. Muscles closed with silver; lowest suture did not include conjoined tendon. Healing per primam. Very slight hydrocele on discharge.	April, 1903. Letter from patient's father, "Hernia apparently recurred. Complains of much pain and of hernia coming down after lifting." Reported recurrence probably a hydrocele. Repeated letter to patient unanswered.
10069 ♂, 45 B	March 6, 1900. Cocain. Muscles so fat nerves could not be identified. A double sac found. Veins excised. Cord not transplanted. Rectus sutured to Poupart's. Note by operator: "One of the most difficult cases I have encountered. Rings were concentric and the double sac made it very puzzling. Abdominal walls fat and thick. Four fingers could be inserted into the external ring."	April, 1903. Examination. Recurrence along whole wound. Patient is not conscious of recurrence. Small hydrocele?
10076 ♂, 45 B	April 10, 1900. Ether. Condition of conjoined tendon not mentioned. Pillars firm. Dissection of sac difficult on account of adhesions. Veins transplanted. Vas left in old bed. Closure with silver. Healing per primam.	April, 1901. Examination by Dr. Halsted. No recurrence. April, 1903. Examination: bulging at site of transplanted veins. Recorded as definite recurrence. March, 1920. Examination by Dr. Reid: "Slight recurrence at site of transplanted veins. Does not come through pillar."
10286 ♂, 31 B	April 25, 1900. Ether. Conjoined tendon wide and firm. Small split in internal oblique. Sac ligated with silk. Cord split, veins alone transplanted. Healing per primam.	Recurred in 8 years. November, 1909. Operated on for recurrence by Dr. Mitchell of Washington. This recurrence took place at the external ring, after heavy lifting. July, 1918. Letter from patient, "No trouble since operation in 1909."
10338 ♂, 27 G	May 4, 1900. Ether. Conjoined tendon poor. Lower part of sac very dark and congested. Cord split. Veins alone transplanted. Hydrocele sac evacuated. Silver sutures. Healing per primam.	July, 1900. Letter from patient, "Hernia cured—swollen cord on left." July, 1918. Letter, "In 1913, a very slight return of rupture." Physician's statement, "Patient has left inguinal hernia 1½ by 2 in. Rupture seems above external ring."
10570 ♂, 18 L	July 7, 1900. Ether. Conjoined tendon good. Sac ligated with silk. Veins large, excised. Vas not transplanted. Healing per primam.	June, 1901. Complete recurrence reported by army surgeon. Subsequent letters returned.

* ♂ represents male.

TABLE 17.—RECURRENCES OF INDIRECT HERNIA—CONTINUED

Surg. No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
10585 ♂, 42 A	July 7, 1900. Ether. Conjoined tendon wide and firm. Sac contained omentum and intestine. Cord split. Veins alone transplanted. Good closure. Healing per primam. Considerable swelling of cord.	Recurrence noticed in about 2 months. July 19, 1901, second operation, "A." Recurrence about 6 cm. in diameter, along lower half of scar. Veins left in transplanted position. Sac not opened. Wound closed by bringing rectus muscle down to Poupart's over mass of subperitoneal fat. Silver sutures. Recurred again in 15 years beneath transplanted rectus. July 21, 1916, third operation, "D." Portion of rectus transplanted at second operation formed a dense band beneath which lay hernial sac. Poupart's very thin, only a few filaments, hence fascia from leg was transplanted. March, 1918. Examination by Dr. Reid: "There is no recurrence. There is a hard lump just at the external ring on left which seems to be indurated tissue."
10060 ♂, 25 L	July 23, 1900. Ether. Conjoined tendon good. Veins excised. Vas accidentally cut, sutured and left in position. Muscles closed with silver. Healing per primam.	April, 1901. Examination: small recurrence at lower angle, with hydrocele. January, 1907. Examination: definite recurrence at lower angle. Hydrocele, very small.
13445 ♂, 25 F	June 3, 1902. Cocain. Conjoined tendon poorly developed but firm. Cremasteric reflex absent. Sac ligated with silk. Veins large, excised. Vas not transplanted. Triangular silver sutures bringing internal oblique and conjoined tendon to Poupart's. Aponeurosis overlapped with fine silk, interrupted. Healing per primam.	July, 1918. Examination: recurrence. Large hydrocele on operated side.
14630 ♂, 33 F	April 30, 1903. Ether. Conjoined tendon fair. Aponeurosis along Poupart's ligament rather weak. Neck of sac sutured with fine silk and transplanted beneath edge of internal oblique. Cord not transplanted. Cremaster sutured to internal oblique. Catgut sutures. Wound healed per primam.	Recurrence in 10 years. Aug. 8, 1914, second operation, "F." Recurrence found at inner angle. Conjoined tendon weak. Large veins excised. Internal oblique sutured to Poupart's including a small layer of cremaster. Flap of rectus fascia reflected and sutured to Poupart's. Varicocele present, also new hernia on opposite side. July, 1918. Examination: no recurrence. Hydrocele size of Bartlett pear.
16859 ♂, 27 G	Oct. 21, 1904. Ether. Conjoined tendon fair. Other structures fairly well developed. Cremaster thin. Previous operation 8 months before on opposite side. Cord not transplanted. First sutures of heavy black silk through internal oblique and cremaster both sides; conjoined tendon included in last suture. Healing per primam.	Recurrence in 8 years. Jan. 31, 1913, second operation, "J." Recurrence found at lower inner angle of wound, strangulated. Cremaster sutured under internal oblique. No subsequent report.
18513 ♂, 52 P	Nov. 29, 1905. Cocain. Internal oblique and conjoined tendon poor. Sliding hernia. Closure of sac difficult and unsatisfactory. Cord not transplanted. Cremaster drawn under internal oblique. Healing per primam.	Recurrence in 15 months. May 15, 1907, second operation, "P." Recurrence at lower angle of wound, strangulated. Veins excised. Usual closure. No subsequent report.

* ♂ represents male.

TABLE 17.—Recurrences of Indirect Hernia—Continued

Surg. No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
16917 ♂, 46 G	March 26, 1906. Ether. Double hernia. Conjoined tendons obliterated. Internal obliques almost like tissue paper. Cremasters well developed. Right side: cord not transplanted; silk sutures through internal oblique and Poupart's including cremaster. Left side: cord not transplanted; same closure as on right. Healing per primam.	July, 1918. Letter from patient: "Left side recurred 6 years after operation, repaired by naval surgeon. Small recurrence on right of 1 year's standing." Two recurrences.
19083 ♂, 28 Q	April 18, 1906. Ether. All structures, especially conjoined tendon, poorly developed. Cord not transplanted. Approximation internal oblique to Poupart's formed a layer so thin as to raise doubt as to its effectiveness in preventing a recurrence. Healing per primam.	July, 1918. Letter from patient, "Rupture came back on right side 6 years ago, and since that have worn a support, have always felt a weakness at the point of operation. Operation never successful."
21565 ♂, 58 K	Nov. 12, 1907. Cocain. Conjoined tendon fair. Strangulated hernia. High ligation of sac, its pedicle being fastened under internal oblique after Kocher's method. Cord not transplanted. Cremaster drawn under internal oblique. Healing per primam.	Recurrence noted in February, 1909, by patient. February, 1909. Examination: recurrence at new external ring. Advised to wear truss. March, 1911. Examination: ring admits finger tip, but hernia is kept back by truss. "It has not been down for 3 years, therefore clinically is perfect."
22032 ♂, 22 C	Feb. 28, 1908. Ether. Conjoined tendon well developed. Slight split in fascia of external oblique. Sac ligated with heavy silk. Cord not transplanted. Cremaster sutured under internal oblique. Healing per primam.	July, 1918. Letter from patient, "Hernia comes down when I work hard." Statement by physician, "Place of operation seems to be swollen size of pigeon's egg and when patient coughs there is a slight protrusion on operated side."
25705 ♂, 21 Misc.	April 5, 1910. Gas. Condition of structures not described. A mass of extraperitoneal fat which lay inside the cremaster interfering with closure excised. Cord not transplanted. Fine silk used in closure except at lowermost angle, where a heavy suture was used. Healing per primam.	Patient says he first noted a recurrence in about 7 months. July, 1918. Letter from patient, "Recurrence took place November, 1910." Physician's statement, "The rupture is in a little better condition now than before operation. Operation seemed a success for several months when the hernia became troublesome again."
26370 ♂, 37 Misc.	Aug. 8, 1910. Ether. Double hernia. Conjoined tendons good on both sides. Left side: high ligation of sac with heavy silk; cord not transplanted; cremaster drawn under internal oblique. Right side: no sac; prehernial weakness; cord not transplanted; similar closure. Healing per primam on both sides.	Recurrence on left in about 1 year and on right in 2 years. July, 1918. Examination, small direct recurrence on left; femoral hernia on right and small rent in aponeurosis through which a little fat protrudes. Findings confirmed at operation March 30, 1920. Two recurrences.
27660 ♂, 36 J	April 19, 1911. Ether. Condition of conjoined tendon not described. Neck of sac transfixed and ligated high. Cord not transplanted. Cremaster drawn under internal oblique. Healing per primam.	July, 1918. Letter from patient, "For the past 4 years I have a partial descent." Subsequent letters unanswered.
28848 ♂, 21 J	Dec. 15, 1911. Ether. Conjoined tendon good. External pillars flabby fairly well defined, also internal pillars. Sac twisted and transfixed. Cord not transplanted. Cremaster drawn under internal oblique. Healing per primam.	Recurrence in 4 years. Oct. 9, 1915, second operation, "D." Recurrence found midway between pubes and internal ring. No evidence of rupture along cord. Cord transplanted. No subsequent report.

* ♂ represents male.

TABLE 17.—RECURRENCES OF INDIRECT HERNIA—CONTINUED

Surg. No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
30247 ♂, 47 H	July 18, 1912. Ether. Internal oblique and cremaster poorly developed. Conjoined tendon not described. Sac ligated high and transfixed. Cord not transplanted. Cremaster drawn under internal oblique. Healing per primam. Postoperative bronchopneumonia.	July, 1918. Report from physician, "Almost ever since operation left side has been weak. A knuckle of intestine seems to bulge into the left internal ring and almost into scrotum."
30273 ♂, 31 H	July 20, 1912. Gas and ether. Condition of structures not described except that internal oblique was rather far separated from Poupart's and there was a rather large opening at posterior thin spot. Cord not transplanted. Closure—cremaster drawn under internal oblique. Healing per primam.	July, 1918. Letter from patient, "Recurrence in about 1 year. Wearing truss." No report from physician.
30374 ♂, 32 M	Aug. 8, 1912. Ether. Conjoined tendon obliterated. All structures weak. High ligation of sac. Veins excised. Cord not transplanted. Cremaster drawn under internal oblique. Two small suture abscesses. Wound drained 10 months.	Recurrence in about 1 month after leaving hospital. Aug. 9, 1917, second operation, "O." Layers of aponeurosis of external oblique had been overlapped and these were retracted backward. Recurrence found in outer angle of wound. Cord not transplanted. Cremaster very thin but it was used under internal oblique. July, 1918. Report from physician, "Cured."
30456 ♂, 57 M	Aug. 26, 1912. Ether. Conjoined tendon poor. Very little cremaster and much fat present, patient weighing 201 pounds. No sac found. Cord not transplanted. Hernia was of sliding variety therefore closure difficult. It was impossible to get a good apposition of structures without some fat between. Cremaster drawn under internal oblique. Healing per primam.	Recurred in 2 months. June 30, 1914, second operation, "M." Recurrence found through external ring which admits five fingers. Sac protruded through separated cremaster muscle. Veins excised. Layer of fascia lata used over external oblique. Silk used throughout. Long and difficult operation. Castration advised; patient refused. No subsequent report.
32438 ♂, 47 D	June 5, 1913. Ether. Conjoined tendon not described. Sac closed by transfixion. Cord not transplanted. Cremaster, which was exceptionally strong, aided considerably in closure. Healing per primam.	July, 1918. Letter from patient, "Slight rupture on right side, though it does not descend into scrotum." No report from physician.
32746 ♂, 70 M	Aug. 26, 1913. Gas and ether. Conjoined tendon good. Hernia as large as two fists. Sac densely adherent as patient had worn truss for years. Sac ligated by transfixion and a running mattress suture followed by ligation en masse. Cord not transplanted. Cremaster drawn under internal oblique. Healing per primam.	Recurrence noticed in 7 months. March 31, 1914, second operation, "J." Recurrence found at inner angle along cord. Cord not transplanted. Conjoined tendon very good indeed and it seemed that in the previous operation this structure had not been properly included in the sutures. Hydrocele found. March 22, 1916. Castration. July, 1918. Examination, no recurrence. Perfect result.
35500 ♂, 67 M	Oct. 14, 1914. Ether. Conjoined tendon not described. Sac ligated with silk from inside followed by multiple transfixion and ligature en masse. Cord not transplanted. Cremaster drawn under internal oblique. Healing per primam.	Nov. 22, 1915, patient was operated on again at Church Home by Dr. Bloodgood. Recurrence was found anterior to the cord. "Marked fibrosis of muscles. No signs of infection."
41358 ♂, 30 O	Dec. 7, 1916. Ether. Conjoined tendon not described. Thick walled adherent sac. Neck twisted, transfixed. Cord not transplanted. Cremaster drawn under internal oblique. Healing per primam.	July, 1918. Letter from patient, "Recurrence on left side in April, 1918, size of walnut" (position of recurrence not mentioned).

* ♂ represents male.

TABLE 18.—Recurrences of Direct Hernia

Surg. No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
8511 ♂, 50 B	Jan. 12, 1899. Cocain. Conjoined tendon firm. Internal oblique divided and transplanted. Closure of neck of sac difficult and accomplished "roughly." Cord transplanted. Healing per primam.	Recurrence, patient states, a few months after operation. Jan. 12, 1904. Examination: recurrence at upper and lower angle of wound. On account of patient's age, operation not advised.
9144 ♂, 39 L	July 11, 1899. Ether. Conjoined tendon obliterated. Great deal of fat and fascia in wound. Cord not transplanted. Rectus withdrawn from sheath and transplanted. Difficult closure. Ether badly taken. Healing per primam.	Recurrence in 6 years. May 11, 1905, second operation, "F." Recurrence found below lowermost edge of transplanted rectus muscle. Internal oblique and conjoined tendon weak. Cord not transplanted. No subsequent report.
10944 ♂, 35 L	Oct. 10, 1900. Ether. Conjoined tendon not wide. Veins excised. Vas not transplanted. Healing per primam.	Recurrence in 13 years. Oct. 9, 1913, second operation, "J." Recurrence found at lower end of wound. Structures fairly good. Large rent in lower end of wound which ran directly into peritoneal cavity. Cord transplanted. Rectus not used. No subsequent report.
21471 ♂, 37 G	Oct. 25, 1907. Ether. Conjoined tendon weak. Cord not transplanted. Suture included sheath of rectus, which was not transplanted, however. Healing per primam.	Recurrence in 2½ years. March, 1911. Examination: recurrence at lowest extremity of incision on left side; direct hernia on right. No subsequent report.
21711 ♂, 32 G	Dec. 20, 1907. Ether. Conjoined tendon fairly well developed. Pillars ring poorly developed. Edge rectus firm. Cord not transplanted. Cremaster sutured between internal oblique and Poupart's. Healing per primam.	Recurrence in 1 year. Jan. 15, 1909, second operation, "G." Recurrence found at lower angle of wound. Conjoined tendon weak. On account of obliterated scar tissue, accurate anatomic sutures scarcely possible. No subsequent report.
22391 ♂, 50 K	May 16, 1908. Ether. Conjoined tendon good; aponeurosis external oblique weak. Sac ligated high. Cord not transplanted. Cremaster sutured to internal oblique. Healing per primam.	Recurrence in 2 years. March 25, 1911, second operation, "N." Recurrence found at inner angle, under conjoined tendon. Neck of sac transplanted. High ligation. No subsequent report.
24985 ♂, 64 C	Nov. 8, 1909. Cocain. Condition of structures not described. Patient extremely fat. Cord not transplanted. Operation as at present, cremaster drawn under internal oblique. Infection in middle of incision.	Recurrence in 6 months. June, 1910. Examination: sac bulges through ring. Sinus at about middle of incision. Probed—no ligature found. July, 1918. Examination: large recurrence. Is wearing truss.
26018 ♂, 22 C	May 30, 1910. Ether. Condition of structures not described. Sac extremely adherent to bladder. High closure impossible owing to proximity of bladder. Cord not transplanted. Closure—using cremaster under internal oblique. Healing per primam.	July, 1910. Examination: patient complains of swelling just below external ring. "This swelling is evidently composed of fat and difficult to reduce. Whether it is a recurrence, or fat which is adherent to the bladder and was impossible to dissect at operation, it is difficult to say." January, 1919. Letter, "I am wearing truss and plan to have another operation done."
27067 ♂, 21 C	Dec. 17, 1910. Ether. Conjoined tendon obliterated. Cremaster well developed. Remaining muscles weak. Cord not transplanted. Closure with transplantation of rectus flap from sheath of rectus in lower portion and cremaster under internal oblique. High closure. Healing per primam.	Recurrence 3 months after operation. Dec. 18, 1912, second operation, "M." Recurrence at site of former operation. Sheath of rectus again used. Veins excised. Good closure.

* ♂ represents male.

TABLE 18.—Recurrences of Direct Hernia—Continued

Surg. No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence*
27777 ♂, 29 N	May 10, 1911. Gas and ether. Conjoined tendon firm. Cremaster not well developed. Dissection of sac difficult owing to fat in the wall. Separation between muscle and Poupart's ligament seemed unusually wide. Cord not transplanted. Cremaster drawn under internal oblique. Wound became infected, opened, irrigated and packed.	Recurrence shortly after operation. July, 1918. Examination: hernia has recurred on right side.
28526 ♂, 48 Misc.	Oct. 9, 1911. Gas and ether. Condition of structures not described. Veins excised. Vas transplanted. Conjoined tendon, edge of internal oblique and transversalis sutured to shelving margin of Poupart's. Catgut and silk for closure. Healing per primam.	July, 1918. Letter from patient, "By fall was again ruptured." Two subsequent letters unanswered.
31688 ♂, 48 J	March 13, 1913. Ether. Conjoined tendon rather weak. Right direct and indirect sacs. Indirect sac empty. Direct sac encased in layers of fat. Stump retracted under internal oblique. Cord not transplanted. Cremaster very much thinned out, not used in closure. Firm closure obtained. Healing per primam.	July, 1918. Letter from patient who is a physician, "Slight recurrence." No conclusive evidence of recurrence is submitted. Subsequent letters unanswered.
33082 ♂, 52 J	Oct. 25, 1913. Ether. All structures weak. Conjoined tendon obliterated. Sac bulges and there is a tendency to formation of indirect sac also. Cord transplanted. Sheath of rectus so weak that it was not used in the repair. Later, however, it was successfully used to cure the recurrence. Border of internal oblique sutured to Poupart's ligament with remnant of conjoined tendon. Healing per primam.	Recurrence in 7 months. Oct. 11, 1916, second operation, "D." Recurrence found directly through abdominal wall. Flap of rectus sheath used to reinforce tissues in region where previous recurrence had taken place. Lengthy operation on account of dense fibrous tissues. July, 1918. Report from physician, "Strong scar."
33324 ♂, 53 J	Nov. 25, 1913. Ether. Direct and indirect sacs on right side. Condition of structures not described, except that cremaster was fairly well developed. Cord not transplanted. Cremaster drawn under internal oblique. On discharge very slight bulging at upper end of scar.	July, 1918. Examination: small recurrence on right side.
35509 ♂, 52 M	Oct. 17, 1914. Ether. Structures for repair extremely weak, especially conjoined tendon. Cord transplanted. Bassini closure. Healing per primam.	Recurrence 3 years after operation. July, 1918. Examination: recurrence on right side.
36842 ♂, 38 D	April 25, 1915. Ether. Structures quite weak, particularly internal oblique. Practically no conjoined tendon. Cord transplanted. Cremaster drawn under internal oblique. Healing per primam.	Recurrence in about 2 years. July, 1918. Letter from patient's physician, "Recurrence is about 2½ inches above external inguinal canal. There is very little trouble caused by it."
39728 ♂, 46 D	May 6, 1916. Ether. All structures exceedingly weak. No special note as to treatment of cord. Closure, cremaster drawn under internal oblique. Reinforcement with fascia transplant—from right thigh. Healing per primam.	October, 1916. Examination by "D": "Recurrence at external ring." Subsequent letter unanswered.

* ♂ represents male.

the rectus muscle in functioning would tend to draw back into its natural position.

Excision of the veins of the cord undoubtedly lessens the likelihood of recurrence, but it is followed by hydrocele in almost 20 per cent. of the cases; when this procedure has been omitted, hydrocele has developed in less than four per hundred. Splitting of the cord with transplantation of the veins was performed in forty-seven cases and gave eight recurrences (17 per cent.). It is interesting to note that in six of these eight cases, the recurrence was found at the site of the transplanted veins.

The use of local anesthesia slightly increases the rate of recurrence but does not seem definitely to have affected the healing of the wound.

The liability to recurrence after operation for strangulated hernia where drainage is not used and with healing by first intention is, as might be expected, not greater than in the ordinary type of hernia.

Infection of the wound greatly increases the liability to recurrence.

The percentage of recurrence in the direct hernias is 18.08, and in the indirect, 5.63.

The mortality, deducting the cases of strangulated hernia, is a little less than half of 1 per cent.

The lines which this study should follow were indicated by Dr. Bloodgood's exhaustive analysis of the facts concerned in the operative treatment of hernia on which failure and success seemed to depend. The relative values of new methods such as the excision of the veins, the splitting of the cord and transplantation of the veins, the transplantation of the rectus muscle and of the sheath of this muscle were more or less definitely appraised. Dr. Bloodgood announced the discovery that hydrocele was likely to follow excision of the veins and told of the conditions under which swelling and atrophy of the testicle might be expected. Thus were emphasized the particulars to be observed by the recorders in their descriptions of the operations for the cure of hernia, and hence it is that there is usually found noted in the histories the details without which an investigation of this kind would be futile. It is unfortunate that this remarkably fruitful monograph of Dr. Bloodgood is not more widely known.

The percentage of recurrence in the cases, traced from time to time through many years and now systematically reviewed, is so high that the purpose in publishing the results is not likely to be misinterpreted. Failures are emphasized in the effort to determine and correct the causes.

Undoubtedly one of the most essential features of the operation is the high ligation of the sac. This fact has been well brought to the attention of the profession by the fairly good results obtained by the

simple operation of Kocher and by the suggestive papers of Laméris,[13] who by his experiments on the human subject seemed to have convinced himself that suture of any of the tissues between the peritoneum and skin was superfluous.

Thus there may remain, as Dr. Halsted believes, little of the original operations of Bassini and himself that is essential except the free and clear exposure of the entire canal which makes possible the high ligation of the sac. The transplantation of the cord and the attempt (quite futile) to reestablish the obliquity of the canal may be omitted; even the suture of the internal oblique muscle to Poupart's ligament may prove to be an unnecessary detail provided the cremaster muscle is well developed and properly utilized.

It is impossible to arrive at a definite conclusion as to the value of transplantation of the cord in preventing a recurrence from the material secured by this study. From the figures below it seems that the percentage of recurrence is very much higher in those cases in which the cord is transplanted but this may be explained by the fact that transplantation of the cord has not been used in recent years save in those cases with exceedingly poor structures. It is by no means a settled procedure, however, to transplant the cord even in such cases and several of the surgeons operating here at present believe that transplantation of the cord increases the likelihood of recurrence in all cases. The influence of the cord is strikingly illustrated by the fact that there is no record of a single recurrence after excision of the cord.

Dr. Halsted believes that a long series of operations performed by one man will be necessary to determine the influence of transplantation of the cord on recurrence and he suggests that it would be wise for transplantation to be performed in alternate cases throughout the series regardless of the condition of the structures. Careful following up of the cases will be necessary throughout a long series of years.

The cremaster muscle has rarely been mentioned by writers on the subject of the cure of hernia. If it is advantageous to suture the free edges of the internal oblique and transversalis muscles to Poupart's ligament, may it not be still more so to make use of a muscle morphologically a part of the internal oblique which normally has a broad attachment to the under surface of the aponeurosis of the external oblique, in other words, to this ligament? The upper bundles of the cremaster may be hardly distinguishable from those of the

13. Laméris, H. J: Zur Behandlung der indirekten Leistenhernia, Deutch. Ztschr. f. Chir. **119**:569, 1912; Ueber die Operation des Leistenbruches, Zentrabl. f. Chir. **45**:764, 1918.

internal oblique, their attachments to Poupart's ligament being almost in line with those of the latter muscle. The free edge of the internal oblique, particularly in its lower part, may not infrequently be approximated to Poupart's ligament only with difficulty and under tension, and the surgeon may have to content himself with suturing it to the fibers of the aponeurosis of the external oblique, which take no part in the formation of Poupart's ligament. Why should we cut away a muscle which so naturally falls into the place where it can serve such a good purpose? When a well developed cremaster muscle, spread out, is mattress-sutured without the slightest tension to the under surface of the internal oblique, it glides into and fills the hollow just vacated by the hernial sac and its contents and may well give the surgeon cause for speculation as to what more is to be gained by suturing the free edge of the internal oblique to Poupart's ligament. Probably something is, however, to be said in favor of this maneuver which is essentially an overlapping of the bundles of one part by another part of the same muscle.

Briefly then, we have in the cremaster a muscle already firmly attached to Poupart's ligament slightly internal to the very line to which we hope to make, with the aid of sutures, the free border of the internal oblique adhere. We must bear in mind the possibility that this border, normally free, may disengage itself when the muscle sutured, perhaps under tension, comes into play. The cremaster muscle, on the other hand, might be expected to remain in the position so naturally assumed. Not infrequently the cremaster is quite as well developed as it was in the case from which the artist, Max Brödel, made the admirable drawing, here reproduced, from Dr. Halsted's paper.[9]

A study of the operative notes of all cases of recurrent hernia shows definitely that the overlapping of the aponeurosis of the external oblique is permanent. The rectus muscle when sutured to Poupart's ligament pulls away from its new attachment, leaving a few scattered bands bound up in masses of scar tissue. The free edge of the internal oblique does not always remain permanently attached to Poupart's ligament, it may undergo fibrous change and in several instances it has been difficult to find the edge of the muscle in the mass of fibrous tissue.

The overlapping of the aponeurosis of the external oblique helps to draw the free edge of the internal oblique to Poupart's ligament and hence to lessen the tension on the sutures placed to hold these two structures in contact. I have demonstrated this recently on the cadaver, and as the overlapping has been found to be permanent it would seem to be a step in the operation that should not be omitted.